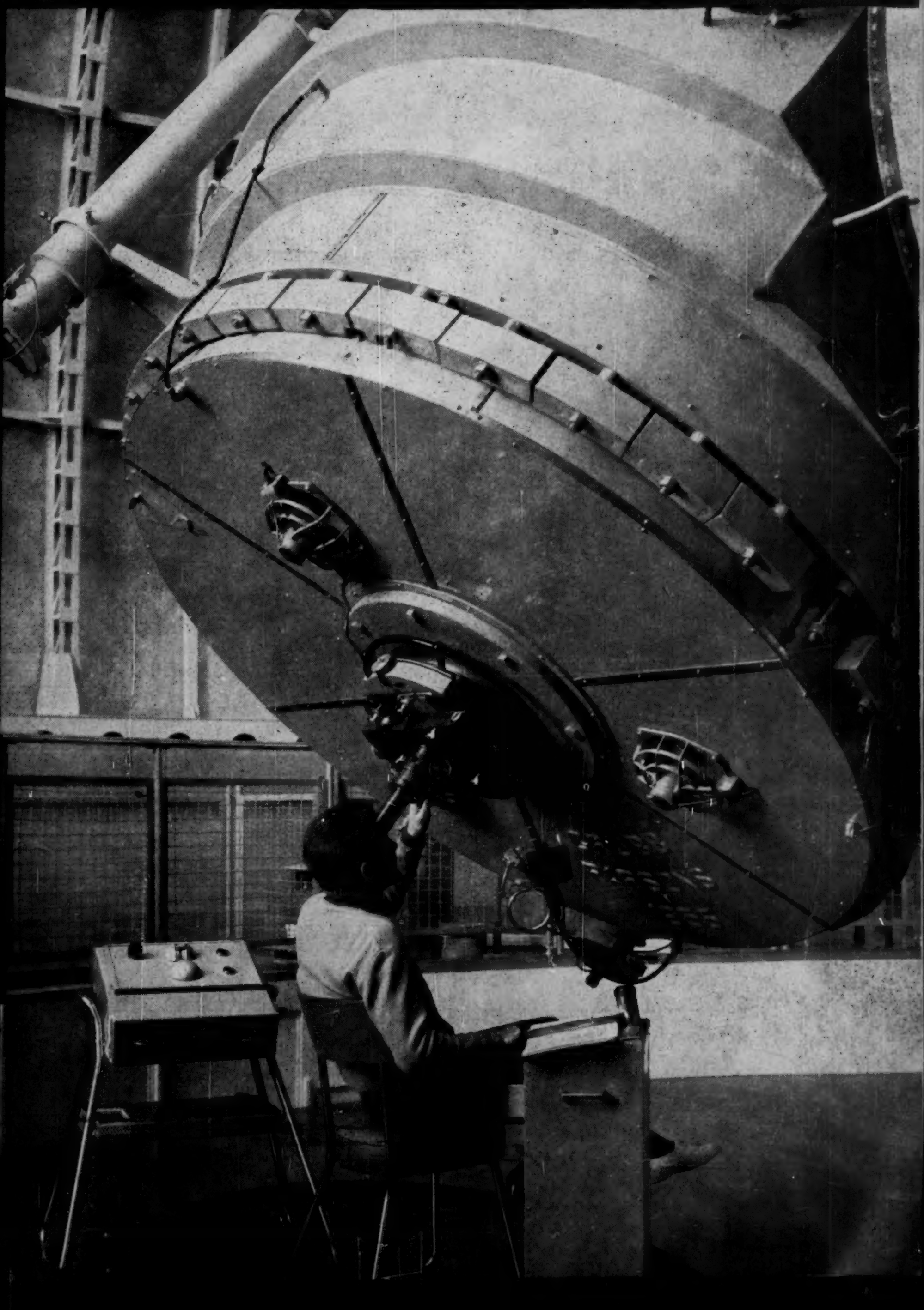

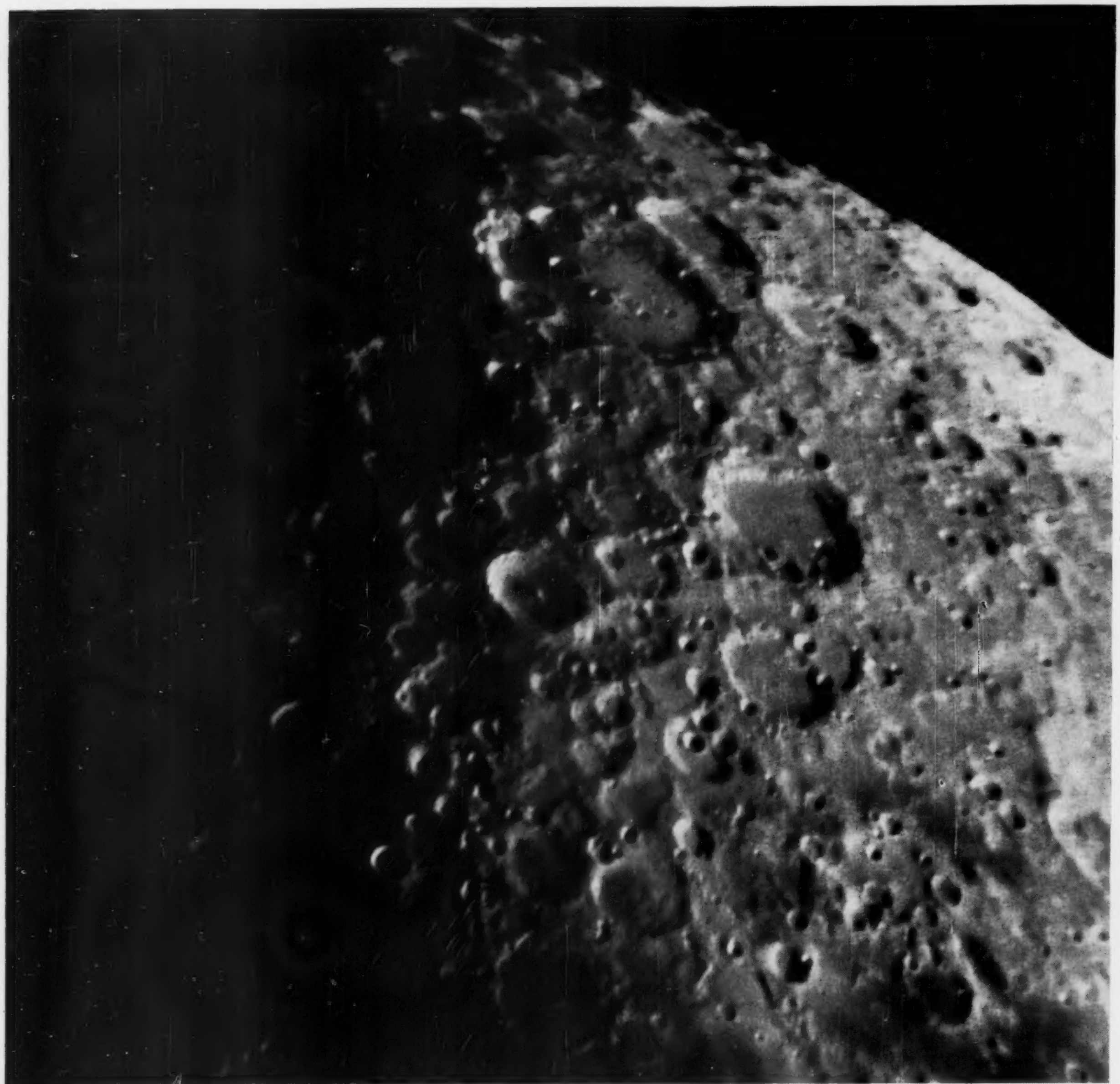

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XXII, No. 1 JULY, 1961

CONTENTS

COVER: Observing at the Cassegrainian focus of Haute Provence Observatory's main telescope. A rising section of floor makes access to the eyepiece easy; a heat shield and fans prevent distortions of the mirror because of the observer's proximity. When the Newtonian focus is used, a counterweight replaces the mirror backing. (See page 4.)

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Solar Magnetism and Sunspot Formation

MOUNT WILSON Observatory was founded more than half a century ago, especially for studies of the sun and sunspots. Now its assistant director, Horace W. Babcock, offers a far-reaching synthesis of current ideas and theories concerning the sun's magnetic field and the nature of sunspots. Although the latter have been among the most thoroughly observed astronomical phenomena, the mechanism of their formation has remained a mystery.

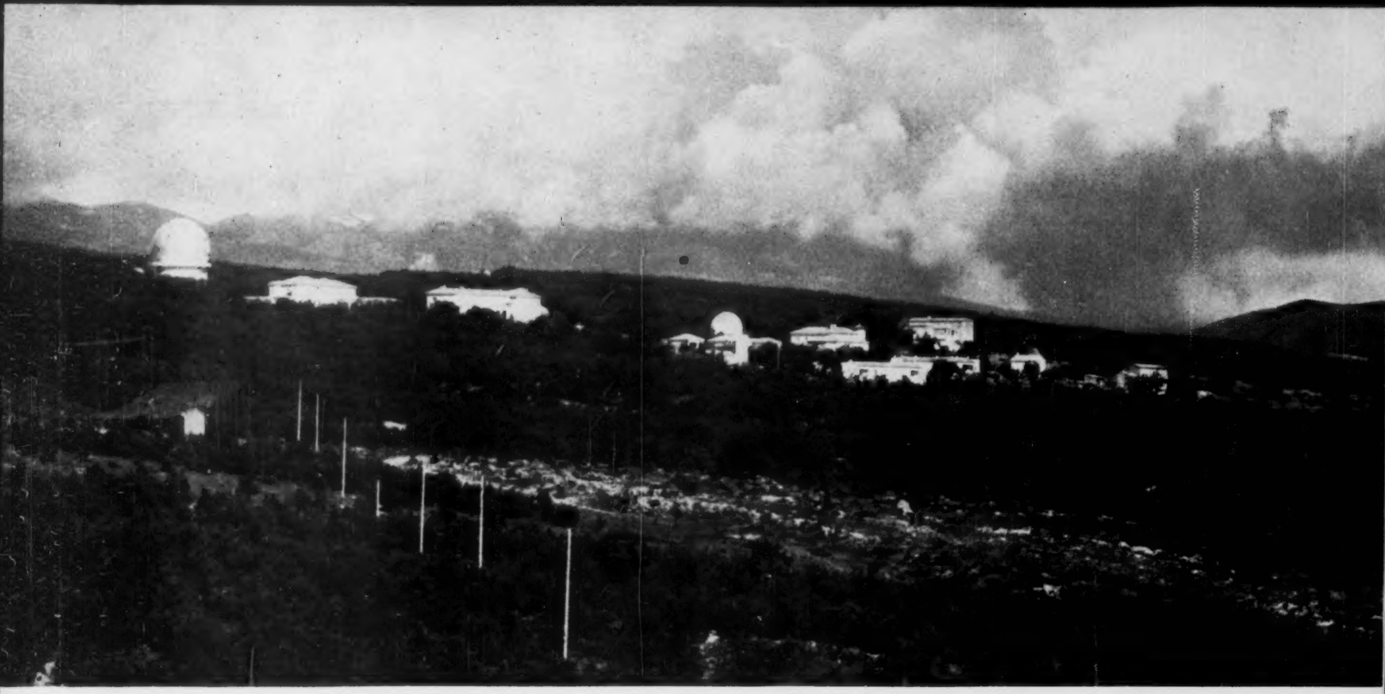
Combining his own studies of solar magnetism with those of his father, Harold D. Babcock, and the theoretical proposals of many other astronomers, Dr. Babcock offers the first comprehensive explanation of why sunspots vary in frequency, size, and latitude, why the magnetic fields of sunspot groups and of the entire sun reverse their polarities every 11 years, and why there are variations in the numbers and sizes of clouds of hot gas that are ejected from the sun and float through the solar system. The Babcocks have pioneered in developing and using special magnetographs for recording daily the details of magnetic flux in the photosphere (SKY AND TELESCOPE, October, 1954, page 423; September, 1958, page 555).

The new theory is based on the fact that all parts of the sun – a sphere of gas 865,000 miles in diameter – do not rotate together. Its equatorial belt rotates once every 25 days, while zones near the pole require 34 days to complete one turn. Thus, every three years the equatorial regions of the sun make five more rotations than sections in latitudes 50° north or south. Dr. Babcock believes that this wraps the lines of force of the main solar magnetic field, which are embedded in the electrically conducting gases of the sun's interior, in opposite directions in the northern and southern hemispheres.

Three years is about the time required for the magnetic wrappings to build up prior to the onset of a new sunspot cycle. As they are wound around the sun in a layer roughly 40,000 miles beneath the surface, the lines of force are stretched and tightened, and the subsurface field becomes as much as 45 times stronger, growing most intense in the intermediate latitudes (about 30° north and south). New-cycle sunspots generally appear in these regions.

The comparatively fast-moving layers near the equator induce twisting of the lines of force to form what Dr. Babcock calls "magnetic ropes." In such a rope there may be local constrictions due to excess twisting, increasing its energy and making it unstable. This may manifest it-

(Continued on page 11)



A general view of the Haute Provence Observatory, showing from left to right an antenna of the radio interferometer, the dome of the 76-inch telescope, workshop, laboratories, the dome of the 47-inch, and living quarters.

France's Haute Provence Observatory

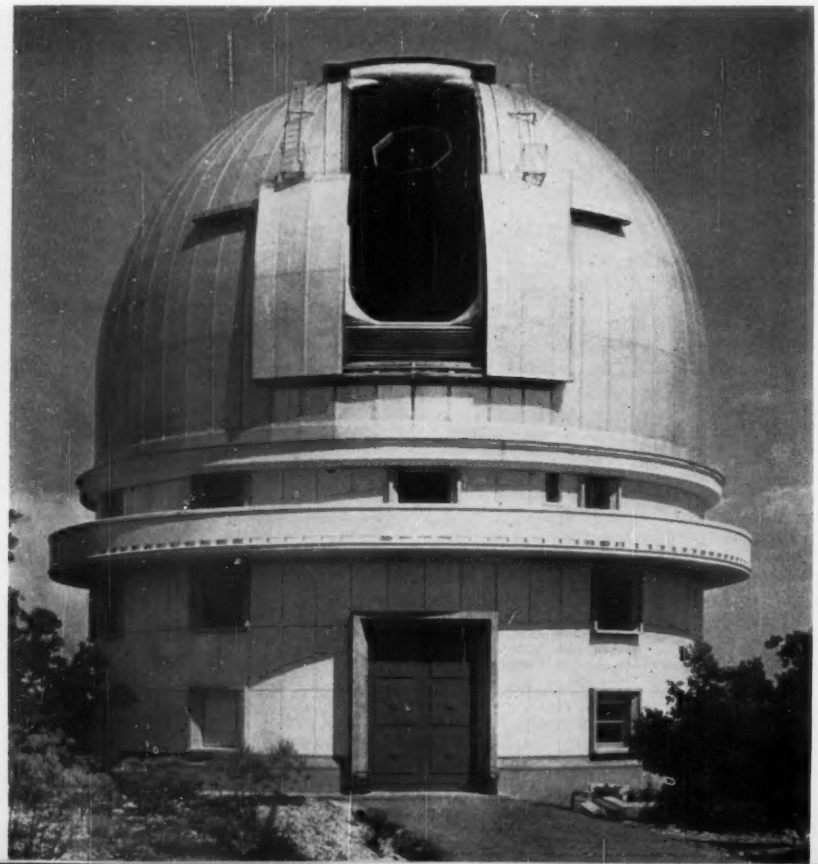
JEAN DUFAY and CHARLES FEHRENBACH, *Haute Provence Observatory*

IN 1936, responding to a wish of French astronomers, Mme. Irène Joliot-Curie, first under-secretary of state for scientific research, decided to establish a well-equipped astrophysical observatory in a favorable climate. The Haute Provence Observatory has since become one of the principal institutions operating directly under the National Center of Scientific Research, which is part of the French ministry of national education.

The site was quickly chosen, thanks to long reconnoitering previously organized by André Danjon, with the collaboration of André Couder and Jean Dufay. Five years of testing with a temporarily mounted 32-inch telescope at Forcalquier verified that the Basses-Alpes region of southeastern France was perfectly suited for large instruments.

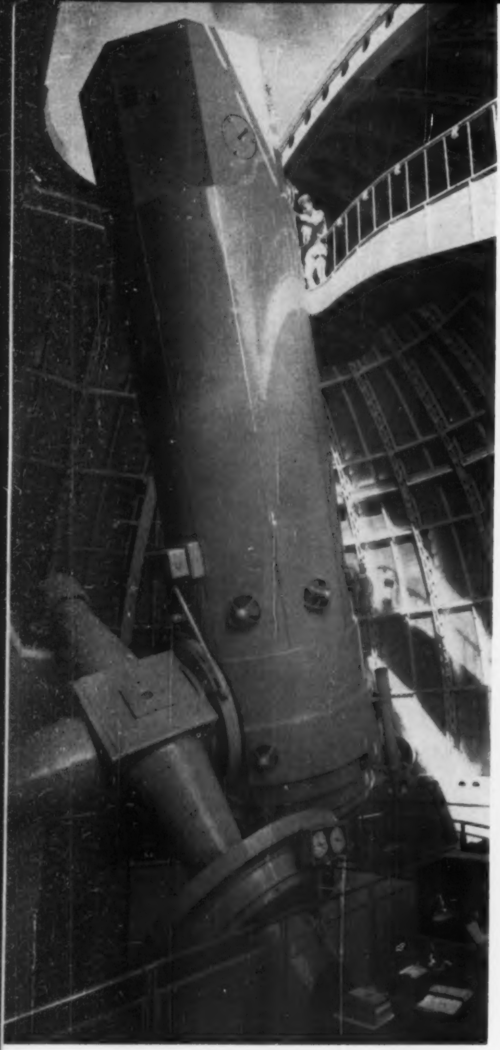
After further detailed site testing, the observatory was constructed at St. Michel, on a rocky plateau 2,000 feet high, less than six miles from Forcalquier and about 60 miles north of Marseilles. This region of Haute Provence, on the last foothills of the Alps, possesses a typically Mediterranean climate, with very few rainy days. An average year has 250 nights when observing is possible, over 100 of which are clear throughout. The number of nights offering almost perfect seeing is also very satisfying.

Undertaken in the beginning of 1938, construction work proceeded very rapidly until the war, under the inspiration of



The dome of the 76-inch reflector, Europe's third largest telescope. The shutter moves up over the dome, and the leaves shown folded at the slit's bottom can be raised as a windscreen.

Inside the dome of the 76-inch reflector. An observer stands at the Newtonian focus near the tube's upper end. His observing platform rides up and down the heavy column (far right), whose base may be moved completely around the edge of the dome. The Newtonian secondary can be turned to reflect light to any one of four positions spaced around the tube, so the plateholder can be conveniently placed. In the lower right an assistant sits at the control console. The telescope may also be used as a Cassegrainian (front cover) or as a coude, whose spectrograph chamber is at the south end of the polar axis, beneath the console. All illustrations with this article are courtesy Haute Provence Observatory.



The main parts of the system for air-conditioning the interior of the 76-inch telescope are visible in this view. Protruding at the top is the porous octagonal inner casing. Fans at the tube's base maintain smooth air flow down the tube, and also help bring the mirror quickly into thermal equilibrium with the outside air. Two fans (see front cover) are placed back of the mirror when the Cassegrainian focus is used. One of the dome's fans appears behind the finder telescope at lower right in the picture.

the great physicist Jean Perrin, successor to Mme. Joliot-Curie. Little was done, of course, from 1940 to 1945; yet the first telescope, a 47-inch, began operation in 1943.

The observatory at present possesses four standard reflectors, with apertures of 24 inches (Cassegrainian), 32 inches (Newtonian and Cassegrainian), 47 inches (Newtonian), and 76 inches (Newtonian, Cassegrainian, and coude). It also has an f/2 Schmidt camera with a correcting plate 12 inches in diameter.

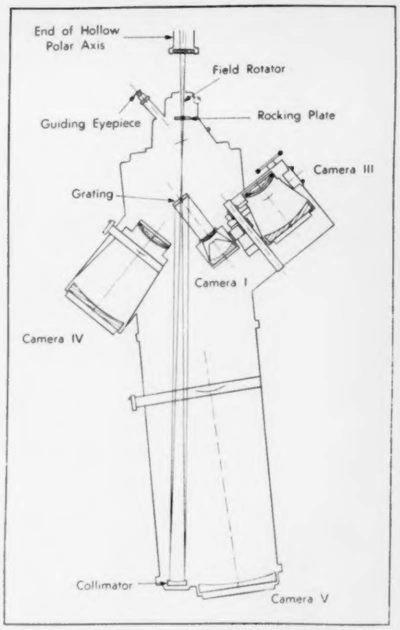
For special work, there are two objective-prism spectrographs of the Fehrenbach type, with apertures of six and 16 inches; a Lyot coronagraph; and spectrographs and photometers for observing the airglow of the night sky. The optical parts of the principal instruments, including the three largest reflectors, were figured by Dr. Couder at the Paris Observatory's optical laboratory. We have a large interferometer for the study of galactic and extragalactic radio sources. Especially important are our laboratory facilities and electrical and machine shops.

The Haute Provence Observatory is at the disposal of all French astrophysicists, who may reside on the grounds while using the facilities for specific projects. Accommodations include a dining room and a 30-room guest house, the Maison Jean Perrin. Observing is the only activity at St. Michel; guest scientists plan their programs and analyze data at their home observatories.

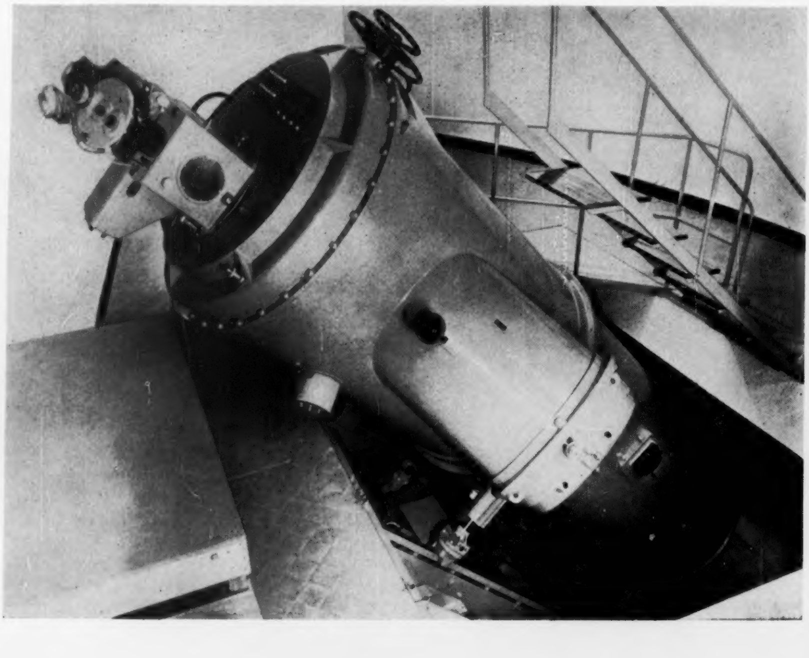
There are, therefore, no astronomers now in permanent residence at the observatory, although coauthor Fehrenbach has been going there for eight consecutive years, and a number of other researchers have worked there several years. On the other hand, an administrator and numerous technical personnel, including engineers, mechanics, electricians, and observing assistants, live permanently at St. Michel, in addition to the usual domestic staff. Administration of the observatory was originally undertaken by coauthor Dufay, director of Lyons Observatory. In 1943 he was joined by Fehrenbach, who is also director of Marseilles Observatory.

A directing committee, presided over by Dr. Danjon, meets regularly to plan the observing schedule and assign telescope time. Foreign astronomers are authorized to work at the observatory under the same conditions as our countrymen.

The largest telescope of Haute Provence Observatory was put in operation in July, 1958. Its primary mirror, used with an aperture of 75 inches, was cast in



At the coude focus is a grating spectrograph. As shown in the diagram above, the field of view is first oriented by a field rotator. The light then passes through a rocking plate that moves the image back and forth to widen the spectrum. The collimating mirror reflects a parallel beam back to the grating, which then throws the spectrum into one of the five cameras. For guiding, the observer views the star's image which is reflected from the polished jaws of the slit. Camera II, not shown, is behind I and III, and all three rotate into position on a single axis; tilting the grating brings the others into play. Below is a side view of the spectrograph, showing the light entrance, guiding eyepiece, and the housing for camera IV. The whole assembly moves on rails.



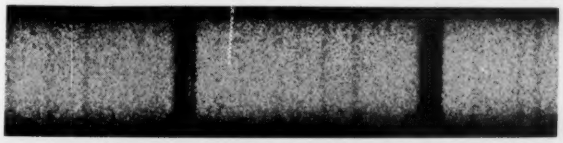
This vast bubble of glowing gas is the planetary nebula NGC 7635 in Cassiopeia, recorded in a one-hour exposure with the 76-inch reflector. With a maximum diameter of about 200 seconds of arc, the nebula appears as an 8th-magnitude object at right ascension 23^h $18^m.5$, declination $+60°$ $54'$ (1950 co-ordinates). South is at the top.

France in 1939, from low-expansion glass; but it could not be ground until after the war. It is relatively thin, weighing only 3,000 pounds; its cell has three fixed supports on the back and two on the side, aligning the optical axis. Thirty balanced supports compensate for flexure. The figure of this mirror is excellent, no aberration exceeding 1/14 wave. Quartz was used for the various secondary mirrors.

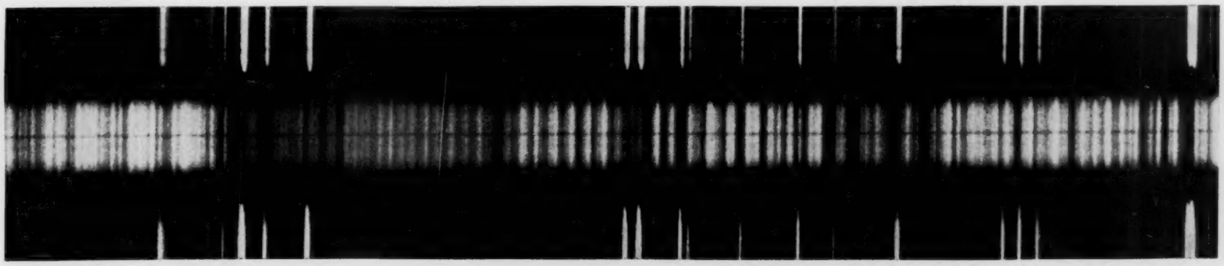
The telescope is pointed, with a precision of one minute of arc, by remote control from a console where the right ascension and declination of the observed object can be read directly. The Newtonian focus (focal length 31.5 feet, f/5) is easily accessible by means of a movable observing platform, no matter where the telescope is pointing in the sky. This platform rides up and down a tall column, which in turn stands on a movable ring-shaped portion of the floor.

Observing at the Cassegrainian focus (equivalent focal length 93.5 feet, f/15) is facilitated by a rising floor 31.2 feet in diameter and having 11.8 feet of vertical travel. At the coude focus (187 feet, f/30), the light is conducted into a large laboratory where a constant temperature is maintained. Finally, the possibility of using the instrument's prime focus has been left open.

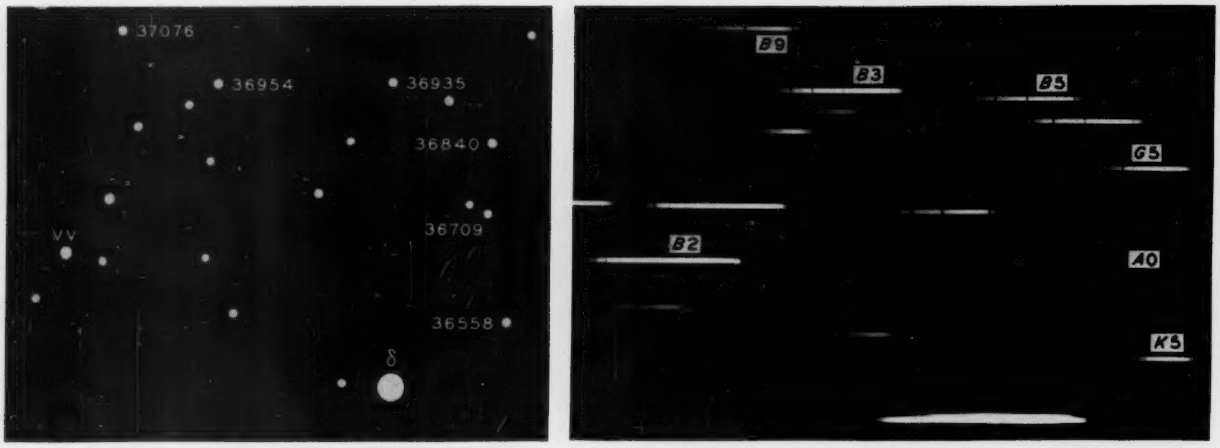
The sodium D lines of Alpha Cygni are widely spaced in this portion of a Haute Provence coude spectrogram.



The dome, 66 feet in outer diameter, is situated above the third floor of a building of reinforced concrete, whose foundation is on bedrock. The north and south piers of the telescope have their own foundation, which anchors them solidly together independently of the rest of the building. The first floor provides a spacious room where the primary mirror can be lowered in its cell by means of a



The region from 5150 to 5230 angstroms in the spectrum of Beta Pegasi, an M-type giant star, taken with Camera V of the coude spectrograph. Dark flutings are a titanium oxide band, converging leftward to a head at 5165 angstroms. This is enlarged about 10 times from a plate whose original scale was 4.1 angstroms per millimeter. The comparison spectra above and below are of an iron arc. A speck of dust on the slit caused the dark horizontal line spanning the star spectrum.



Two pictures of the same star field near Delta Orionis: left, a direct exposure, and right, an objective-prism photograph taken with the 6-inch camera shown at bottom right on this page. Stars are labeled by their Henry Draper Catalogue numbers and by their spectral types. The A- and B-type spectra mainly show dark lines of hydrogen; the G5 and K5 stars have many metallic lines. The spectrum plate is an 80-minute exposure; north is to the right, east above.

traveling crane, to be aluminized in a 7$\frac{1}{2}$-foot stainless-steel tank.

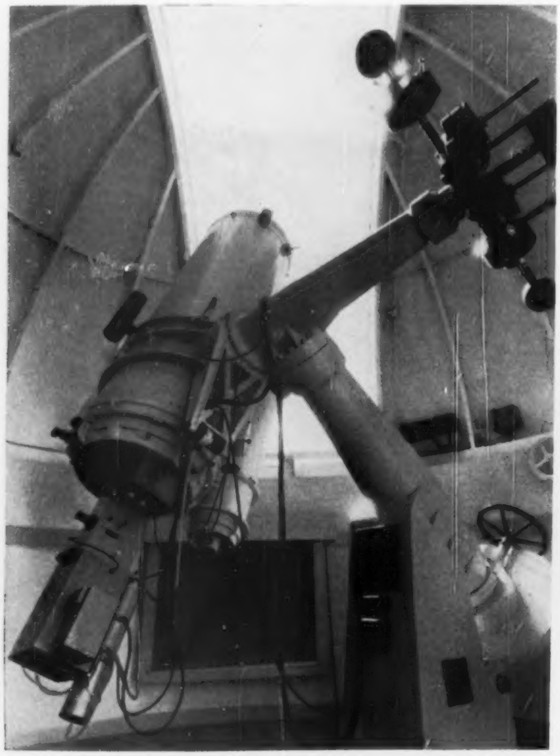
Particular precautions are taken to reduce temperature fluctuations in the dome's interior and to avoid air turbulence. The dome covering consists of two sheets of aluminum mounted on steel ribs and separated from each other by an insulating air space filled with crumpled aluminum foil.

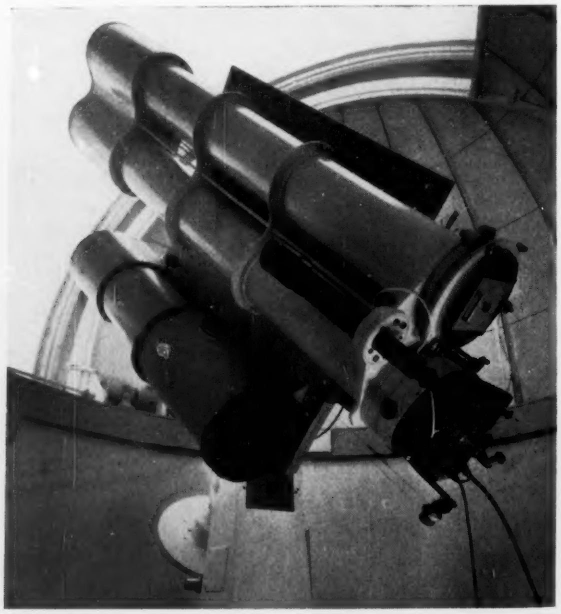
It is desirable that the rays of light entering the dome and telescope travel within a laminar flow of air, so that no turbulence will exist along the light path. The observing slit can be partially closed with movable shades, leaving an opening only eight feet square above the upper end of the telescope. The tube is double-covered. Exterior air that enters it is drawn through the inner casing of porous nylon and blown out into the dome by six fans placed on the metallic outer casing of the tube not far from the primary mirror. Eight larger fans are mounted in the dome opposite the slit. The slight vacuum they create in the building causes a smooth inward flow in front of the telescope.

This system, due to Dr. Couder, has been found in careful tests to be very effective. Almost perfect images can be obtained, if external atmospheric turbulence is also rather small. Currently, observations at the coude focus are being made of stellar images whose diameters are between 0.3 and 0.8 second of arc.

A large spectrograph of Fehrenbach design, constructed by the Society for Research and Studies in Optics and Related Sciences, is installed at the coude focus, on a pier rigidly connected to the telescope supports. The spectrograph can be moved out of the way very rapidly, though it weighs over two tons, to permit use of other observing equipment, for example the Lallemand electronic image converter.

The 8-inch collimating mirror is 14.8 feet in focal length. Two Bausch and Lomb gratings, six by eight inches, are instantly interchangeable from a control





Above: Mounted on a large pegboard are (top) the 6-inch objective-prism camera with its guiding telescope and, below them, a 12-inch Schmidt camera.

Left: The observatory's 24-inch reflector equipped with a Lallemand image converter, which greatly shortens exposure times.

panel at the top of the spectrograph, and send the light into any one of five cameras. The largest of these has a 31-inch mirror of 7.38-foot focus, and a photographic plate 14 inches long. With the first grating, having 1,200 lines per millimeter, it covers the spectral region from 3600 to 7200 angstroms in three sections. The dispersion is 4.1 angstroms per millimeter in the violet and visible regions, and 3.6 in the extreme red. This camera can record spectra of 8th-magnitude stars in a six-hour exposure. With the second grating (771 lines per millimeter), the same camera produces dispersions of 3.2 angstroms per millimeter in the violet and 6.4 in the near infrared.

The other cameras furnish dispersions in the neighborhood of 10, 20, 40, and 50 angstroms per millimeter. The two fastest cameras are f/1.1, and are particularly suited to the observation of nebulae.

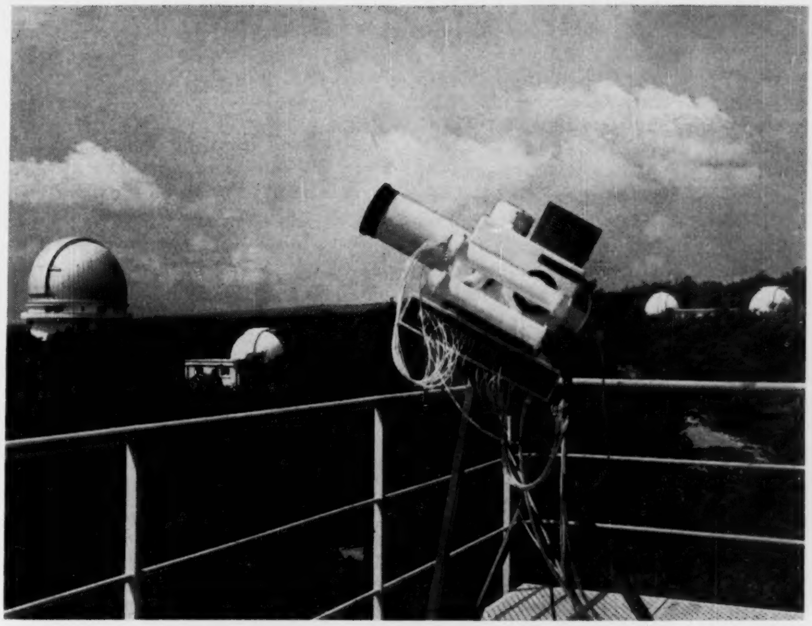
More than a thousand plates have been made since the spectrograph was installed in July, 1959, and as the reproduced spectra show, definition is excellent.

Several other spectrographs have been planned for the Cassegrainian focus. A recently completed one is specially intended to measure radial velocities. Another will soon be installed for studying faint stars and nebulae in the visible and near-infrared spectral regions. Finally, an extremely fast spectrograph (f/0.47) is planned to be used at the Newtonian focus.

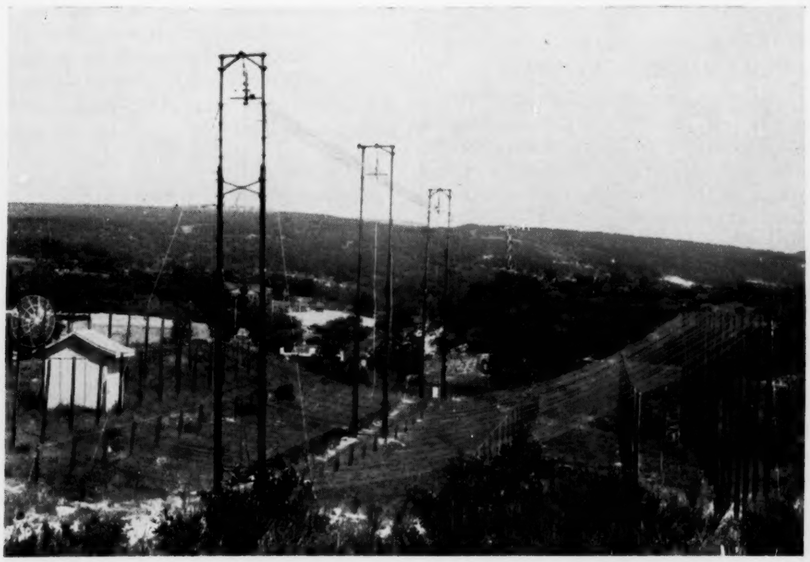
Two novel Haute Provence telescopes are 6- and 16-inch refractors with objective prisms for the determination of radial velocities of stars. Their design was conceived by Fehrenbach and developed by Dr. Danjon. An objective-prism camera has the advantage of being able to photograph the spectra of many stars at once, but it is not possible to interpose a laboratory spectrum to furnish wave length calibration. However, if two exposures are made, with the prism rotated 180 degrees between them, each star produces two spectra, one with blue to the left, the other with blue to the right.

The prisms used are compound ones that do not deviate light for a chosen wave length, this property holding over the entire field of the telescope. Hence the two spectra of a star will be symmetrical about this wave length, but displaced by an amount depending on the Doppler shift of the star, and therefore on its radial velocity. This method has proved very successful for the wholesale measurement of the line-of-sight velocities of stars.

Other instruments at the observatory are of the conventional type. We hope to keep pace with new developments in instrumentation, so that French astrophysicists will have at St. Michel every facility to meet their observing requirements.



This instrument, designed by the French astronomer J. E. Blamont, is used for the study of free sodium in the upper atmosphere. The telescope receives radiation from atmospheric sodium, which is measured by the fluorescence it causes in a tube of heated sodium vapor within a magnetic field.



One of the sections of the observatory's interferometer array, with a four-foot parabolic dish at the far left.

GEORGE A. DAVIS, JR., DIES

A widely known Buffalo, New York, astronomer died on June 4th at the age of 71. George A. Davis, Jr., was an authority on astronomical history and especially on star names, concerning which he contributed several articles to SKY AND TELESCOPE. He founded the Buffalo Astronomical Association in 1930, and was director of the Buffalo Museum of Science's Kellogg Observatory from 1937 to 1958. For many years he taught adult evening classes in astronomy at the museum.

Mr. Davis served on the three-man committee of experts that the American Astronomical Society chose in 1942 to establish a uniform pronunciation of star and constellation names. This led to an officially adopted list of approved pronunciations, which was reprinted in the March, 1958, issue of this magazine, page 220.

His versatility is indicated by the fact that he had practiced law for over 40 years, was a distinguished Arabic scholar, and had played professional baseball with the New York Yankees and the Boston Braves before World War I. At the time of his death, he was writing an extensive book on the history of constellation and star names.

NEWS NOTES

TEMPERATURES ON MERCURY

The great difference in temperature between sunlit and permanently shadowed portions of the planet Mercury, which always turns one face toward the sun, has been investigated theoretically by J. C. G. Walker at Yale University. Two sources of heat are involved, solar radiation and the radioactivity of the planet's material.

On the sunward side, radioactive heating is very minor compared with the sun's direct rays. If Mercury radiated as a black body, the theoretical temperature at the subsolar point would be 621° Kelvin when the planet is at its average distance from the sun. During the 88-day orbital revolution, the computed subsolar temperature varies from 695° at perihelion to 565° at aphelion.

The night side is warmed primarily by internal radioactivity, with only a minor contribution from solar heat conducted through the interior. The radioactive heat generation has been evaluated by assuming Mercury to have the same composition as a chondritic meteorite, one gram of which liberates 1.6 ergs of thermal energy per year. Dr. Walker finds that the permanently shadowed surface is only at about 28° K. It was at one time suggested that meteoritic bombardment might supply enough energy to raise the night side's temperature appreciably, but the new calculations show this effect to be quite insignificant.

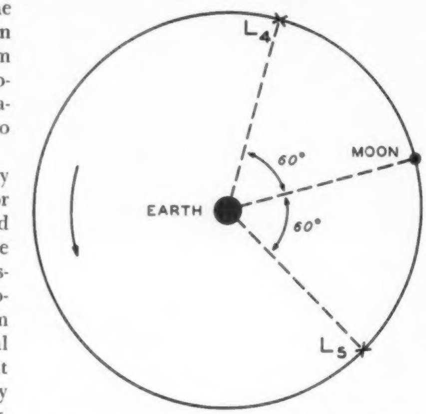
For Mercury's internal temperature distribution, the Yale physicist assumed that heat conductivity and the distribution of radioactive material are both uniform throughout the interior. The central temperature turns out to be nearly 5,000° K., slowly diminishing outward; it is about 2,000° at 300 miles below the surface. These figures are valid only for Dr. Walker's particular model, and are at best an approximation to conditions in the actual planet.

NEW NATURAL SATELLITES OF THE EARTH?

The discovery of two faint, cloudlike objects circling the earth at the same distance as the moon has been reported by the Polish astronomer K. Kordylewski, at Krakow Observatory.

His find is the result of many years of searching, based upon the idea that the most likely locations for additional natural satellites are the Lagrangian points of the Earth-Moon system. These places have the property that small bodies located near them will persist in stable orbital motion. Two of these points, known as $\mathbf{L}_4$ and $\mathbf{L}_5$, are at the same distance from the earth as the moon, the first 60 degrees ahead of the moon in its orbit, the other 60 degrees behind. In the Sun-Jupiter system, the corresponding points are each the center of a group of Trojan asteroids.

Very few details are available concerning Dr. Kordylewski's discovery. His two libration clouds are both near the $\mathbf{L}_5$ point, several degrees apart, and were recorded on four photographs taken on March 6th and April 6th of this year. He suggests that similar objects may be found near the $\mathbf{L}_4$ point, 60° east of the moon. In *Circular* 1760 of the International Astronomical Union, Dr. Kordylewski provides ephemerides for both libration points, remarking that for observers in northerly latitudes the $\mathbf{L}_5$ clouds will be unfavorably placed until January, 1962, but the other point could be searched beginning this September.



As the moon travels around the earth, these L-points form equilateral triangles with the earth and moon. K. Kordylewski's two clouds are in the vicinity of the $\mathbf{L}_5$ point.

As this issue goes to press, no observations of Dr. Kordylewski's clouds by other astronomers have been received.

INTERFERENCE COATINGS ON ALUMINIZED MIRRORS

The reflection of visible light from metals can be increased by applying a pair of transparent dielectric films in the same manner as glass lens surfaces are coated to increase their transmission. In the Russian journal *Optics and Spectroscopy* (January, 1961), E. I. Levitina gives the results of experiments in which reflecting layers of aluminum, chromium, nickel, palladium, and rhodium were coated with films of silica and titanium dioxide.

In every case the over-all reflectivity was increased, from about 88 per cent to 91 per cent for aluminized surfaces such as commonly employed for telescope mirrors. But even greater advantage was gained in mechanical stability and resistance to deterioration. The Soviet scientist writes:

"After three to five hours testing in a corrosion chamber with periodic moisture condensation and a drop in temperature from 50° to 35° C. in the course of each hour (cycle), a layer of aluminum on glass completely disintegrates. After 100 hours an aluminum mirror of the same type, with films of silica and titanium dioxide, still does not show a trace of corrosion, and furthermore, the mirror retains the initial high reflection coefficient. The reflection coefficients of aluminum mirrors with films were lowered only to 89 per cent after exposure for one hour in a 10-per-cent solution of caustic soda, whereas a metallic layer on the mirror without films is completely dissolved under the same conditions in 30 to 45 seconds. Aluminum mirrors with films can remain for an hour in concentrated sulfuric acid without a change in reflection coefficient, whereas mirrors without films are completely dissolved in 20 to 30 minutes."

The deposited films of silica and titanium oxide were obtained by a relatively simple chemical process, the hydrolysis of ethyl esters of orthosilicic and orthotitanic acids.

SHAPES OF LUNAR CRATERS

Undamaged lunar craters are to a first approximation circular, although the curvature of the moon's surface makes those situated near its limb appear quite elongated by the effect of foreshortening. But there is a systematic tendency for the craters to be slightly elliptical, according to Ernst J. Öpik, University of Maryland, partly as a result of changes in the rotation period and shape of the moon since they were formed. In the *Astronomical Journal* for March, 1961, he writes:

"According to the theory of tidal evolution, in the immediate past the moon was nearer to earth, when its tidal distortion may have been considerable. Impact craters formed at that time must subsequently have undergone deformation

IN THE CURRENT JOURNALS

N.A.S.A. LOOKS AHEAD, by Morton J. Stoller, *Spaceflight*, May, 1961. "Major Mercury flights will probably continue for several years. . . . Following the Atlas-Agena flights, the Saturn vehicle would be used for full-scale development and prototype flights. Earth-orbital missions, using the final spacecraft, could conceivably begin in 1966, with circumlunar missions following as soon as the state of both technical and aeromedical knowledge permits such flights."

THE TEMPERATURES OF THE PLANETS, by Cornell H. Mayer, *Scientific American*, May, 1961. "Various observers have now used radio techniques to measure the temperatures of Venus, Mars, Jupiter and Saturn. Some of the results are in line with advance expectations; others have come as quite a surprise."

when the moon assumed its present more nearly spherical shape.

"Actually, impact craters never are expected to be exactly circular; a slight ellipticity is predicted by the theory of impact, depending upon the angle of incidence and the 'explosiveness' of the collision. The [tidal-rotational] deformations superimposed on this random ellipticity will lead to elongation in a certain preferential direction, depending upon the location of the craters in relation to the tidal and rotational axes."

From measurements of 178 craters in G. P. Kuiper's *Photographic Lunar Atlas,* Dr. Öpik calculates that the observed crater ellipticities indicate an origin when the moon was between 30,000 and 50,000 kilometers from the center of the earth, roughly a tenth of its present distance. The period of revolution of the moon was much shorter then, and its rotation was faster, resulting in a more pronounced flattening at the poles. The tidal bulge was larger than at present. Hence a circular impact crater, formed on the moon at that time, would become deformed as our satellite receded, both because the polar flattening decreased as the rotation slowed down and because the tidal bulge became less pronounced at the greater distance.

The Maryland astronomer believes that the larger lunar craters, considered in this study, probably were formed by an intense bombardment of short duration, possibly by earthbound fragments in a cloud or ring surrounding the geocentric orbit of the growing moon. Previously he had found (SKY AND TELESCOPE, March, 1960, page 285) that the number of craters less than 13 kilometers in diameter was consistent with meteoritic impacts continued over the past 4.5 billion years.

NAVAL OBSERVATORY LIBRARY

The largest library of any astronomical observatory in the United States is in Washington, D. C., at the U. S. Naval Observatory. It contains over 55,000 catalogued volumes, and many periodical sets. The collection was begun in 1811-15 by F. R. Hassler under the authorization of Thomas Jefferson, and thus is older than the observatory itself, which was established in 1830.

In charge of the Naval Observatory library is Marjorie S. Clopine, who writes in the February issue of *Special Libraries:* "The resources of the library make reference work especially rewarding. Typical reference questions concern such facts as: the official action ending the use of the astronomical day; coordinates of the observatory erected in Independence Square [Philadelphia] to observe the transit of Venus in 1769 (This observatory attained greater prominence as the structure from which the Declaration of Independence was first read publicly.); and literature about the surface of the moon, related to the problem of constructing an observatory thereon."

Besides being a very complete working assembly of modern astronomical literature, the Naval Observatory library also contains a notable collection of 500 rare astronomical works printed before 1800. Six of these are from the 15th century, the earliest being the first illustrated edition of Hyginus' *Poeticon Astronomicon* (1482), with its beautiful woodcuts representing the constellations.

Among other early books at the Naval Observatory is *Machina Coelestis,* by Johannes Hevelius, published at Danzig in two parts, 1673-79. The second part is extremely rare, for almost the entire edition was destroyed when a dismissed servant returned to set fire to Hevelius' house.

SOLAR MAGNETISM AND SUNSPOT FORMATION

(Continued from page 3)

self as a loop in which the lines of force exert a magnetic pressure comparable to the gas pressure. The magnetic buoyancy of the loop will make it rise and break through the solar photosphere, where it forms a bipolar magnetic region with a positive and a negative magnetic flux area.

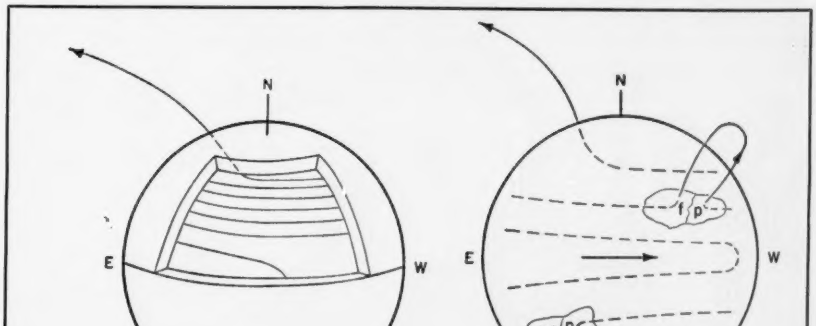
The magnetic lines of force that link the two parts of the bipolar region loop up into the high solar atmosphere. Dr. Babcock's calculations show that ample magnetic rope is formed within the sun to account for the two or three thousand bipolar areas observed in each 11-year solar cycle.

Because of the opposite direction of twisting in the two hemispheres, the polarities of leading and following areas are interchanged, just as actually observed. The concentrated magnetic flux bundle piercing the solar surface inhibits local convection of the hot gases (as proposed by L. Biermann in 1941) and a sunspot may form. Sunspots are found only within bipolar magnetic regions, especially while the latter are young and compact. The observed spiral filaments in the chromosphere near spots may be explained by the twisting of the magnetic rope, and the duplicity of spots by the fact that the rope is looped up through the surface.

Expanding in the atmosphere, the leading part of a loop moves toward the equator as it ages, to be canceled by merging with vertical legs of other loops. Meanwhile the following part drifts poleward, and in combination with other loops reduces and finally replaces (with opposite polarity) the original magnetic field of the sun. This process, which involves severing and reconnecting the lines of force in the corona, need be only one per cent efficient. It requires 11 years for completion, resulting in an unwrapped field of reversed polarity for the start of the next cycle.

As the vertical legs of the loops are canceled, they leave the upper parts drifting freely in the corona. These detached loops may travel outward through the solar system carrying entrapped ions and electrons. By means of instruments carried by artificial satellites, such clouds of charged particles have been observed as they pass the earth.

Reporting his theory in the March issue of the *Astrophysical Journal,* Dr. Babcock characterizes the process as a freely running oscillator that lacks stabilization. The sun's differential rotation supplies only enough energy to drive it for a few thousand years. If this is indeed the driving force, the problem of the maintenance of that rotation assumes new interest.



Two stages in the solar cycle, according to Horace W. Babcock. At the left, the submerged magnetic lines of force have been drawn out in longitude and wrapped around the sun. At the right, magnetic flux loops have risen through the photosphere, each loop forming a bipolar magnetic region. Diagrams courtesy the "Astrophysical Journal."

Radio Ursigrams

MARTIN H. POTTER

MANY amateur astronomers engaged seriously in observing the sun lack current and accurate information from professional astronomers concerning solar happenings. Radio Ursigrams provide one method by which an amateur, with little expense or trouble, can obtain the latest reports on sunspots, prominence activity, auroras, ionospheric disturbances, and other related phenomena.

The name *Ursigram* comes from the French abbreviation for International Scientific Radio Union (U. R. S. I.). Ursigrams are messages, coded for brevity, that report data from 139 co-operating observatories and laboratories in all parts of the world. They are sent to users by radio, telegraph, and mail.

About 30 different types of Radio Ursigrams are distributed, each devoted to a specific class of information. Of these, CHRAG messages are especially valuable to amateur astronomers. They are transmitted daily from Ste. Assise, France, by station FYP, 91.15 kilocycles per second, at 12:08 and 13:08 Universal time. All broadcasts are in international Morse code (emission type A1), at a speed of about 20 words per minute, and include other Ursigram messages besides the CHRAG bulletins.

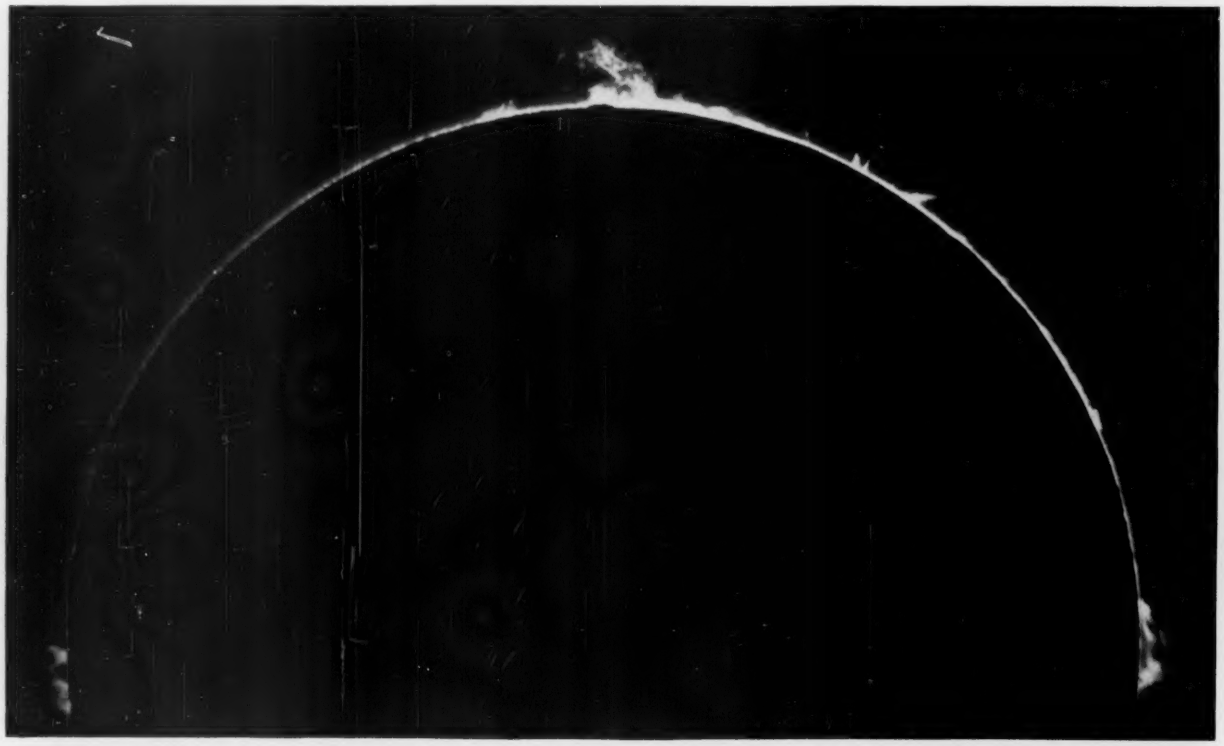
A sample bulletin might read: CHRAG 17510 71221 78212. The decoded text tells: "Meudon Observatory, France, reports that on the 17th at 12 hours Universal time the sunspot number was 112, a high-quality determination. There was medium activity on the disk, and slight prominence activity. The sudden disappearance was noted of a prominence in the sun's western hemisphere, 80° of longitude from the central meridian, with a latitude between +20° and +30°. This same prominence had been observed one day earlier as of importance 2 on a scale of 1 to 3."

While a full key to the CHRAG code is too lengthy to be reprinted here, its nature will become clear from a partial explanation of this message. The first word, CHRAG, identifies the kind of message and the code used. The second group, 17510, tells first the day and tenth of day (Universal time) as 17.5, while 10 identifies the observatory as Meudon.

Information about the relative sunspot number is contained in the next group, 71221, which may be symbolized by *WWWAP*. If *WWW* in the message is from 000 to 299, it gives the sunspot number directly, but characterizes it as a poor determination. If *WWW* is between 300 and 599, the determination is of medium quality, and 300 must be subtracted to obtain the sunspot number; if between 600 and 999, the quality is high, and 600 must be subtracted. On the rare occasions when the actual sunspot number is greater than 299, *WWW* is still transmitted as 299, 599, or 999, depending on the quality of the observation. The true number is then given at the end of the message. The two remaining symbols *A* and *P* in this group are one-digit numbers characterizing, respectively, the level of general solar activity and the level of prominence and filament activity.

The fourth group, of five numbers, describes the location and characteristics of an activity center or prominence that has suddenly disappeared, and may be followed by other such groups.

Another series of Ursigrams uses the CHROM code to report solar chromospheric and photospheric activity. Others deal with the corona, solar radio noise, calcium plages, and further specific phenomena. Amateur users of the solar flare detectors described by David Warshaw (*Radio-Electronics,* January, 1959, page 41) or Philip Del Vecchio (SKY AND TELESCOPE, August, 1959, page 546) will find the UFLAR bulletins very profitable.



This photograph, showing prominences at the sun's limb typical of those reported in Ursigrams, was taken on June 26, 1956, with Walter Semerau's solar telescope in Kenmore, New York. The PROMO code would be used to report this activity in detail, giving prominence positions, importances, and times of occurrence.

USSPA

Sunspots

1. — Content of the message

— Wolf relative number of sunspots.
— General activity indices for disk and limb.
— Area of spot groups.
— Position, importance and Brunner type of groups (Code **A**).

2. — General form of the message

USSPA JJTII aaabc eefff QXXYY gijkk
(a) (b) (c) (d) (e) (f)

(f) importance and number days group, Brunner classification and spot count
(e) quadrant, angular meridian distance and heliographic latitude
(d) serial number and area of spot group
(c) relative sunspot number, general activity indices for disk and for limb
(b) date and time of observation, identification
(a) key word

3. — Definition of symbols

(a) USSPA = key word (**U** = interchange, **sunspot**, Code **A**)

(b) JJ = Greenwich date of observation
T = time of observation in tenths of the Greenwich day
II = indicator of the observatory (table **II**)

(c) aaa = relative sunspot number for date (observatories should give R + 600 if observation quality is good; R + 300 if fair, and R if poor)
b = general activity index for disk, scale of 1 (small) to 5 (great) activity
c = general activity index for limb 1-5

(d) ee = serial number of spot group (assigned by reporting observatory on the basis of observations on preceding days)
fff = area of spot group in tens of millionths of solar hemisphere

(e) Q = quadrant (heliographic coordinates) containing the spot group (table **Q**)
XX = angular meridian distance, in degrees
YY = heliographic latitude, in degrees

(f) g = importance of group, scale 1, 2, 3
i = number of days group observed since limb passage or first appearance on disk
j = Brunner classification of region, A = 1, B = 2, etc.
kk = spot count

4. — Tables of Coding

(**II**) *Indicator of the observatory*

See Table (II), Section 2.

(**Q**) *Quadrant*

1 = NE	4 = NW
2 = SE	3 = SW

Note: Omit A, B, J type spots (URSI Information Bulletin, nº 94, Nov.-Dec. 1955).

An excerpt from the "Manual of Ursigram Codes," giving an explanation of USSPA messages. All groups after the code name are sent as numbers, for which the letters in section 2 are symbolic generalizations.

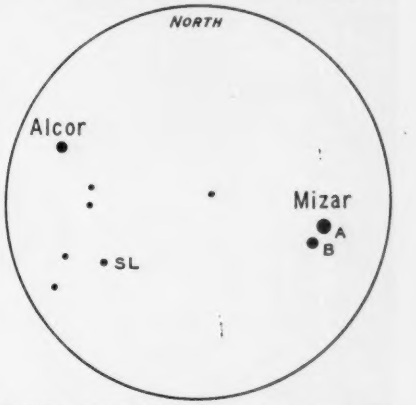
These permit quick evaluation of a flare's intensity and additional properties as observed at many other stations. Even if the user of these bulletins is unable to copy the code transmissions himself, he can probably find an amateur radio operator or experienced short-wave listener who is willing to help.

The schedules for the transmission of Ursigrams from data centers in France, West Germany, Japan, and India are published in the *List of Special Service Stations* distributed by the International Telecommunication Union at Berne, Switzerland. Complete information regarding schedules, decoding methods for each of the 30-odd types of bulletin, and more, is contained in the *Manual of Ursigram Codes,* available from the General Secretary of U. R. S. I., 7 Place Émile Danco, Brussels 18, Belgium. The $8.00 price for this loose-leaf book includes corrections and supplements, which are mailed to the user from time to time.

QUESTIONS... FROM THE S+T MAILBAG

Q. In observing Mizar and Alcor with a small telescope, Mizar seems to split into two components. Is this star double?

A. Yes. In addition, both of the components, labeled **A** and **B** in the accompanying chart, are spectroscopic binaries. The star marked **SL** in the field diagram



is Sidus Ludovicianum, an 8th-magnitude star that can be seen in even small instruments.

Q. What is the limiting magnitude for visual and photographic observations with the 200-inch telescope?

A. Stars of about magnitude 19 can be seen with averted vision; the photographic limit is magnitude 23.

Q. How many telescopes are there in the United States having apertures of 20 inches or more?

A. According to G. P. Kuiper and Barbara M. Middlehurst's book *Telescopes,* there are 49 in this country. Of these, 33 are reflectors, 12 refractors, and four are Schmidt cameras.

Q. Was there a bright comet in late 1948 visible in the Southern Hemisphere?

A. Yes. This was Comet 1948l, which was first seen from South Africa during a total eclipse of the sun on November 1st, leading to the name "eclipse comet." It reached 2nd magnitude, and could be seen from the southern United States.

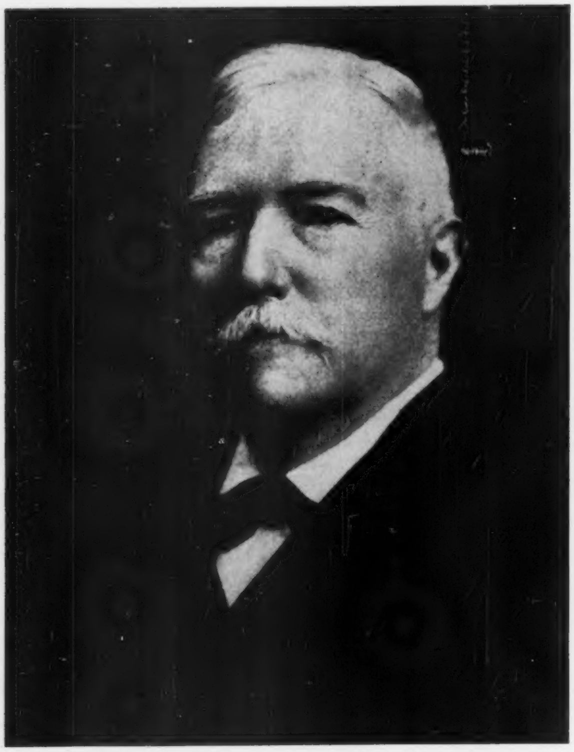
Q. How are rotation rates found for asteroids or satellites too small to show disks?

A. By measuring variations of a rhythmic nature in the light reflected by the body. If it is irregularly shaped, it will reflect different amounts of light as it turns, and the time required for these variations gives the period of rotation.

Q. How many natural satellites of planets in our solar system can be seen with a 10-inch reflector by a skilled observer under the most favorable conditions?

A. Possibly 13: in addition to our own moon, four of Jupiter, five of Saturn, two of Uranus, and one of Neptune.

W. E. S.



E. E. Barnard and Milky Way Photography

Otto Struve, *National Radio Astronomy Observatory**

Edward Emerson Barnard (1857-1923) was one of the greatest astronomical observers of all time. Discoverer of 16 comets, he made numerous precise measurements of double stars, satellites, and star clusters. His most fundamental contribution was to employ photography to study the Milky Way. Yerkes Observatory photograph.

When I ARRIVED at Yerkes Observatory in 1921 as a refugee from war-torn Russia, one of the first persons I met was an elderly gentleman who was looking at the barograph in the observatory library, and quietly complaining that the barometric pressure was going down and the night would presumably be cloudy. This was Edward Emerson Barnard, the most famous member of the Yerkes Observatory staff, generally recognized as the most capable and productive astronomical observer in the world. I knew him for only 18 months, for he died on February 6, 1923, in his 66th year.

Although he published some 900 scientific papers, his name is now seldom mentioned in astronomical literature. Nevertheless, all astronomers active today are in one way or another building upon the foundation of his accurate measurements of celestial bodies, and his thousands of Milky Way photographs, obtained at Lick Observatory and later at Yerkes. It is surprising that references to Barnard's contributions are not more often cited by those who have followed in his footsteps. His name and work have become part of astronomical history sooner than is normal at the present time. This has happened, perhaps, mainly because later generations of astronomers found nothing to criticize in Barnard's work, and associated him with the great names of earlier decades.

Barnard was born in Nashville, Tennessee, on December 16, 1857, and throughout his life he remembered the flashes of artillery at the battle of Nashville during the Civil War. In his youth he survived an attack of cholera when that plague raged across the southern states.

Because of the need to support his impoverished family, he attended public school for only two months, beginning work as a photographer's assistant in Nashville at the age of nine. His principal duty was to point a heavy enlarging camera at the sun. To make the work easier and to save time for reading and study, he built himself a simple equatorial mounting with a driving mechanism, so that the camera automatically followed the sun's diurnal motion. By 1877 he had saved enough money to purchase a 5-inch equatorial refractor, and he was already well-known as an active amateur astronomer when shortly afterward he joined the American Association for the Advancement of Science.

At the 1877 meeting of the association in Nashville, Barnard met the famous Simon Newcomb, director of the U. S. Nautical Almanac Office, and at the age of 42 a leader in mathematical astronomy. Newcomb advised Barnard to secure a firm grounding in mathematics, but the latter's limited resources restricted him to studying at home. While Barnard became proficient in elementary mathematics, he was never thoroughly acquainted with the more advanced branches, and his fame rests upon his success as an observer rather than as a theoretician.

On May 12, 1881, at the age of 23, Barnard discovered his first comet in the morning sky near Alpha Pegasi, but the object was not formally announced, and no other astronomers observed it. Hence the first comet officially bearing his name is the one he detected on September 17th that year in Virgo. He continued for many years searching the sky, eventually discovering a total of 16 comets. On five different occasions, Barnard received the $200 prize given by H. H. Warner, of Rochester, New York, for each unexpected comet discovered by an American observer. This made it possible for Barnard to buy a modest home for himself and his family, which was known in Nashville as the "comet house."

In 1883 Barnard was appointed to a small fellowship at Vanderbilt University in Nashville, which enabled him to attend courses while taking care of its observatory. He received the bachelor of science degree from this university in 1887.

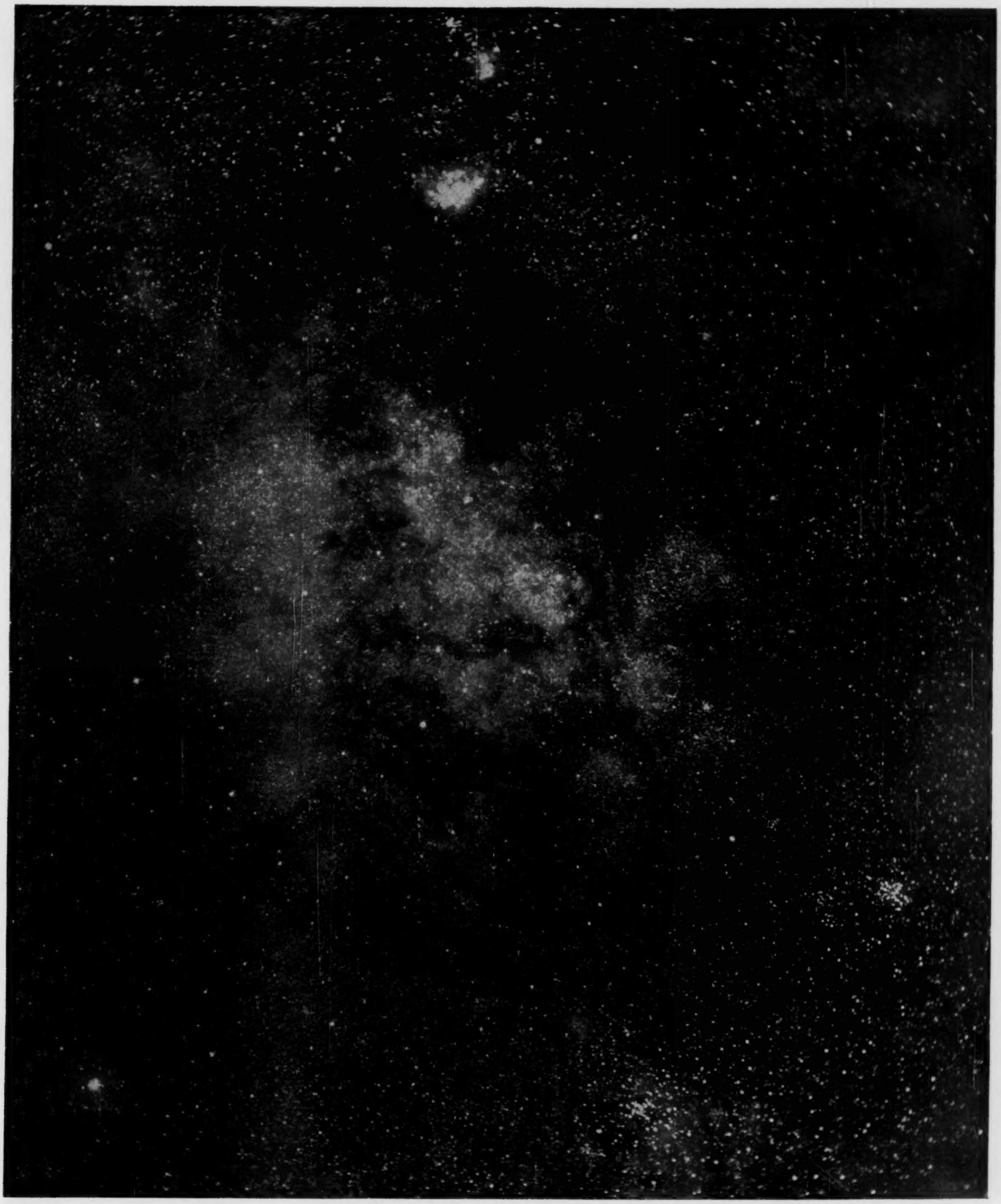
That same year, E. S. Holden, the first director of Lick Observatory, offered Barnard a position at the new institution, where he remained until 1895. One of his greatest discoveries with the 36-inch refractor was the fifth satellite of Jupiter. This faint moon was found on September 9, 1892, and observed by Barnard on many occasions both at Mount Hamilton and Yerkes Observatory. Even with very large telescopes it is an extremely difficult object, visible only when seeing and transparency are excellent.

Barnard's most important contribution was his astronomical photography with varied types of instruments, especially wide-field photographic objectives. He revolutionized the art, although experiments in the application of photography to astronomy had started before Barnard was born.

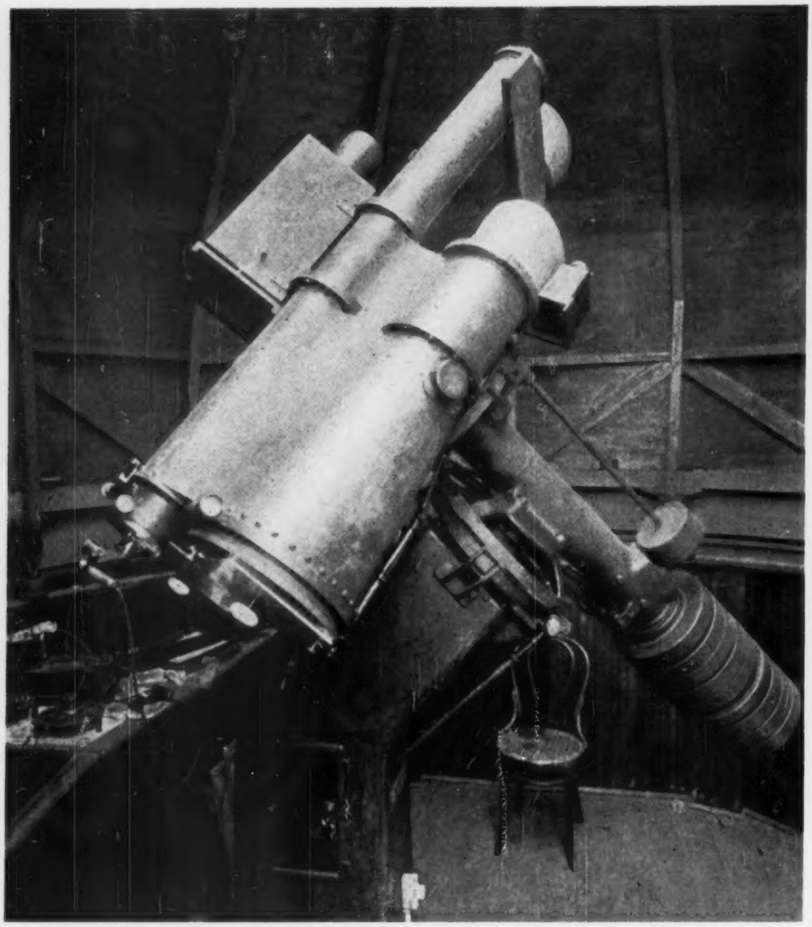
The daguerreotype process was invented in 1839, and within a year the American amateur J. W. Draper had succeeded in obtaining a picture of the moon. Because the daguerreotype method and the wet-plate process (invented about 1850) were very slow, it seemed at first that the only hope for any success lay in photography of the sun, moon, and possibly the planets and some of the brighter stars. There was no prospect of photographing faint stars or nebulae.

One difficulty in the early attempts was

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



The intricate splendor of the Milky Way was first revealed by Barnard's long-exposure photographs. He took this picture of the Sagittarius starclouds with the 6-inch Willard lens at Lick Observatory on August 13, 1895, a three-hour exposure. Barnard called these starclouds the finest in the sky, so full of splendid details as to defy adequate description. This view is centered at right ascension $17^h\ 55^m$, declination $-28°$, with north toward the top and a scale of $1\frac{1}{2}$ degrees per inch. The very bright star in the lower left corner is Epsilon Sagittarii, while Delta (dim because of its redness) is one inch from the left edge and five inches from the top. The star clusters M6 and M7 are at lower right. The nebulous cluster M8 is conspicuous $1\frac{1}{2}$ inches from the top edge and $3\frac{1}{4}$ inches from the left, with the Trifid nebula, M20, above it and slightly to the right. The cluster M21 is above the latter at the very top of the picture. Seen in silhouette against the bright starry background are many dark wisps and patches. One of these, looking like a tiny ink drop, is just above the picture's center. Three inches below it is another small dark nebula, likened by Barnard to a parrot's head, with a star for the eye. Reproduced from Lick Observatory "Publications," Vol. XI (1913).



The Bruce instrument at Yerkes Observatory as it appeared when Barnard used it. Three telescopes are rigidly mounted together. Seen fully in the center is a 6¼-inch f/5 Voigtländer, and above it on the left a 5-inch guiding telescope. Behind the latter, mostly hidden, is the main 10-inch Bruce camera, whose 12-inch plates cover a field 13½ degrees square. A 3.4-inch Clark lens of 20-inch focus is in the auxiliary camera at upper left.

that existing refractors were corrected for the yellow part of the spectrum to which the eye is most sensitive, whereas the photographic emulsions were sensitive to blue light. L. M. Rutherfurd in 1864 made a great step forward by making the first telescope lens corrected especially for photographic wave lengths. Another major advance was the introduction of the relatively fast dry plate about 1880. However, in 1900 Barnard wrote, "What is shown by the best lunar photographs has not yet approached that which can be seen with a good telescope of very moderate size." In a certain sense this remains true even today.

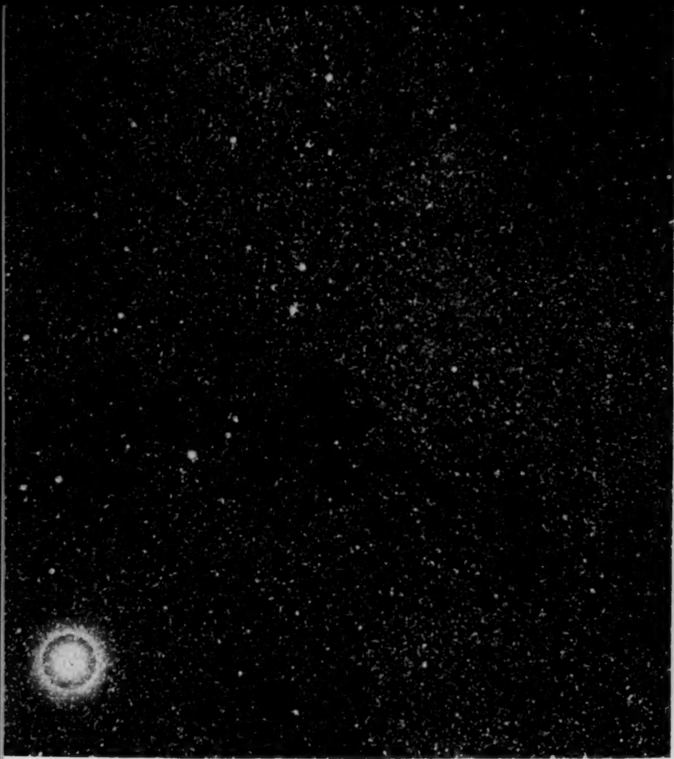
The first daguerreotype of the sun and its spots was obtained in 1845 by H. L. Fizeau and L. Foucault in France, and Berkowski at Königsberg Observatory took the first picture of the solar corona during the total eclipse of July 28, 1851. By 1900, photography was used extensively in solar work, and many photographs of the planets, comets, and asteroids had been obtained. The greatest advances had been made, however, in the field that at first seemed to hold no promise for photography — the stars and nebulae. This had come almost as a surprise to astronomers.

In the fall of 1882, a bright comet appeared in the southern sky, inducing David Gill at the Cape of Good Hope to borrow a camera from a local photographer. His pictures showed the comet well, but even more impressive was the great number of stars recorded on the negatives. At this time, the Paris astronomers Paul and Prosper Henry, who were making maps of faint stars along the ecliptic, had reached the Milky Way and were discouraged by the immense numbers of stars encountered. On seeing Dr. Gill's pictures, they realized the potentialities of photography for making charts, and it may be said that the active application of stellar photography began with this incident.

As for nebulae, the first photograph of the most conspicuous one visually, Messier 42 in Orion, was made in 1880 by Henry Draper, son of J. W. Draper. Before the Henry brothers had constructed their first photographic telescope, much controversy had raged over the existence of a nebula connected with the star Merope in the Pleiades, which was promptly confirmed by their photographs. According to Barnard, one of these "showed the Merope nebula just as the best observers had drawn it and at the same time filled the entire group of stars with an entangling system of nebulous matter which seemed to bind together the different stars of the group with misty wreaths and streams of filmy light, clearly all of which is beyond the keenest vision and the most powerful telescope. This was a revelation. . . . It began to dawn upon astronomers what great possibilities lay in the photographic plate for the detection and study of nebulae."

In the 1880's, the best photographs of nebulae were obtained by A. A. Common in England, with his 36-inch reflector. Barnard has stated that a nebular photograph by Common and one of a rich star field in Cygnus by the Henry brothers first called his attention to the astronomical value of photography, and that thus he conceived the idea for his proj-

Compare this picture of a group of dark clouds in the Aquila Milky Way with three other views of the same field on the facing page. F. E. Ross used a 5-inch f/7 lens of his own design for this four-hour exposure on July 17, 1931, at Mount Wilson Observatory. The faintest stars in this reproduction are about 16th magnitude. From the Ross-Calvert "Atlas of the Northern Milky Way," University of Chicago Press (1934).



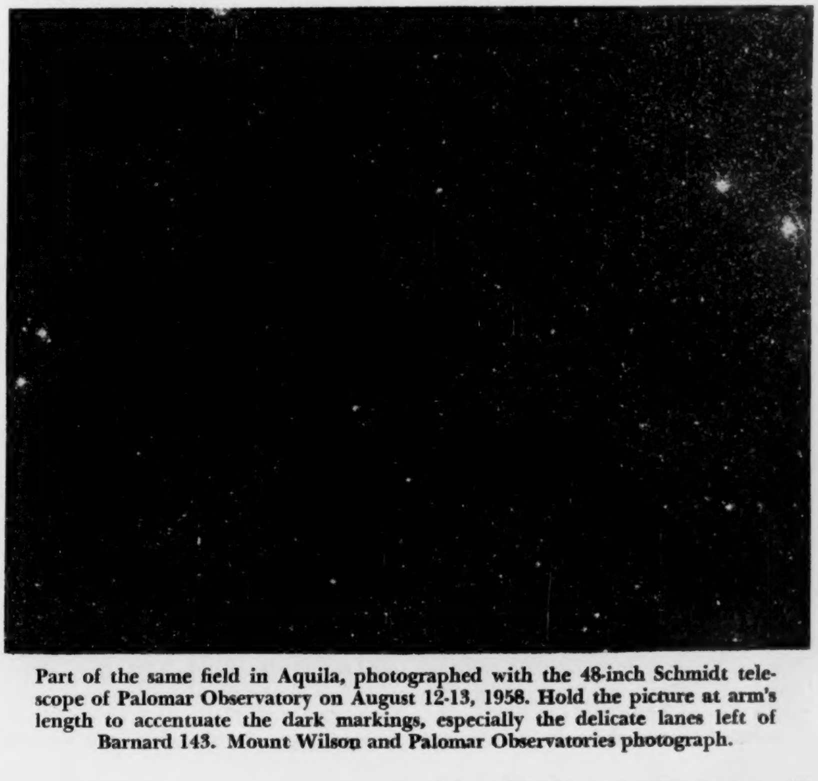
Two more views of the dark clouds northwest of Altair, whose overexposed image is near the lower left corner of the first picture. This was taken by Barnard on October 12, 1892, an exposure of four hours 20 minutes with the 6-inch Willard lens. Comet 1892 V was discovered on this photograph; its faint, fuzzy trail is nearly an inch from the top, 1⅜ inches from the right edge. The second photograph is also by Barnard, a four-hour exposure with the 10-inch Bruce telescope on August 27, 1905. The C-shaped dark marking just below center is No. 143 in Barnard's catalogue of obscuring nebulosities. Slightly to the right and below is his No. 142. To the left of the former, just at the edge of the picture, is another, less conspicuous dark nebula, Barnard 340. The peculiar shapes of many of these markings led him to the correct conclusion that they are opaque foreground objects, rather than vacancies in the star clouds.

ect of photographing the Milky Way.

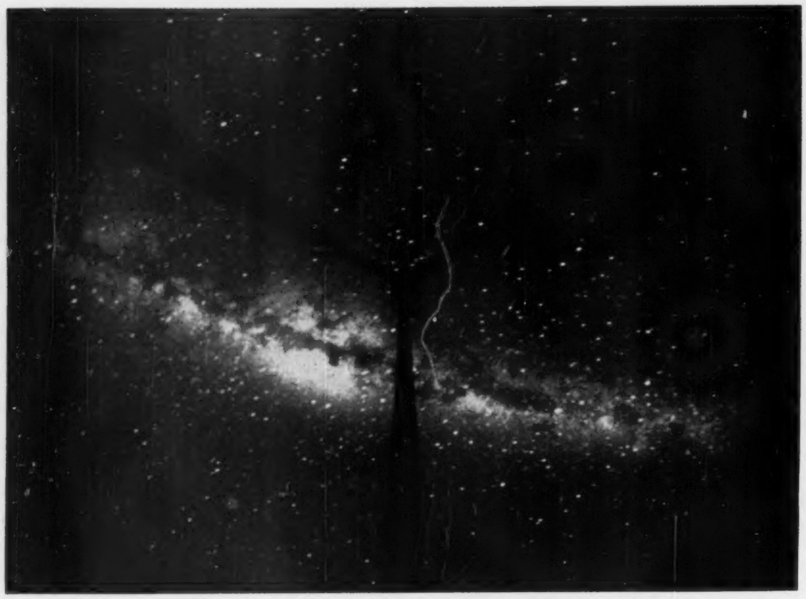
He soon realized the advantages of a fast, wide-angle camera over ordinary telescopes for recording the Milky Way. His early work at Lick was done with the 6-inch Willard lens (named after a photographic stock dealer), which dated back to the days of wet-plate portraits, when a camera of great light-gathering power was needed to shorten the time of portrait sittings. Lick Observatory purchased this lens with funds donated by C. F. Crocker, after it had been used by an amateur astronomer to take excellent photographs of the solar eclipse of January 1, 1889. Volume XI of the Lick Observatory *Publications* (1913) contains 129 photographs, mainly of the Milky Way and comets, made by Barnard with the Willard lens. In addition, many of his fine pictures appeared in various issues of the *Astrophysical Journal.*

Barnard's last series of photographs of our galaxy was published in 1927 as *A Photographic Atlas of Selected Regions of the Milky Way.* This included 50 long exposures obtained with the 10-inch Bruce refractor at Yerkes and at Mount Wilson observatories. (He had spent part of 1905 as a guest investigator at Mount Wilson, taking the Bruce telescope with him.) This instrument and its dome were erected with money donated by Catherine W. Bruce, a generous patron of astronomy who had provided several observatories with large photographic telescopes. It consists of two f/5 cameras of 10 and 6¼ inches aperture, rigidly bound together on the same mounting with a 5-inch guiding telescope.

To maintain the highest possible quality of the atlas, Barnard himself made the reproducing negatives, and personally inspected each of the more than 35,000



Part of the same field in Aquila, photographed with the 48-inch Schmidt telescope of Palomar Observatory on August 12-13, 1958. Hold the picture at arm's length to accentuate the dark markings, especially the delicate lanes left of Barnard 143. Mount Wilson and Palomar Observatories photograph.



The Milky Way from Aquila to Carina, photographed by A. D. Code and T. E. Houck in infrared light with a Greenstein-Henyey wide-angle camera. Note the distinct belt of obscuration, much as in an edge-on view of a spiral galaxy. The three radial shadows are caused by the three-legged camera support. Reproduced from the "Astrophysical Journal," March, 1955.

prints required for an edition of 700 copies. He had drafted detailed descriptions of the individual pictures before his death in 1923, and the work was completed for publication by his personal assistant and niece, Mary Calvert.

An amusing incident occurred during the preparation of the atlas prints. They were all made in Chicago and shipped to Yerkes Observatory by truck. During one of the Chicago gangster wars, a shipment of photographs was completely pierced by a bullet. Of course, the pictures had to be replaced, but the damaged ones for a long time remained objects of curiosity to visitors at Yerkes Observatory.

An important feature of the *Atlas* was the key charts that identified all the brightest stars and the dark and luminous nebulae. Barnard included in the introduction a catalogue of 349 dark nebulae. Awareness of these dark regions in the Milky Way can perhaps be traced back to Sir William Herschel's expression, "Surely, this is a hole in the heavens!" But their first systematic study and correct interpretation are due to Barnard.

In 1919 he wrote: "I did not at first believe in these dark obscuring masses. The proof was not conclusive. The increase of evidence, however, from my own photographs convinced me later, especially after investigating some of them visually, that many of these markings were not simply due to an actual want of stars, but were really obscuring bodies nearer to us than the distant stars. In this way it has fallen to my lot to prove this fact. I think that there is sufficient proof now to make this certain."

Barnard's catalogue of dark clouds was the only one until 1960, when an atlas of galactic dark nebulosities by D. S. Khavtasi was published in the Soviet Union. This consists of six charts containing stars down to apparent magnitude 6, and with a co-ordinate grid showing galactic latitude and longitude. Apparently Khavtasi used the Ross-Calvert atlas and southern Milky Way photographs. The dark nebulae are shown by shaded areas, indicating three different amounts of opacity, and are labeled with arbitrary numbers ranging from 1 to 762. However, many of the numbered objects are really condensations in larger obscuring aggregates.

As has long been known, the dark nebulae tend to lie close to the central line of the Milky Way. In the Soviet atlas, the widest distribution in galactic latitude occurs in the vicinity of the galactic center, where the dark features are spread approximately uniformly between latitudes $-10°$ and $+15°$. In the region of Cygnus and Vulpecula, this range is from about $-7°$ to $+5°$.

G. A. Shajn and V. Hase had found in 1952 that the dark clouds of the Milky Way are generally elongated parallel to the galactic plane. (Usually this has been interpreted in terms of an interstellar magnetic field whose lines of force lie predominantly in the galactic plane.) Such a trend is also noticeable in the new atlas, but individual clouds often depart from it strikingly.

Another catalogue of dark nebulae is now being prepared by Mrs. B. T. Lynds from the Palomar sky survey photographs taken with the 48-inch Schmidt telescope.

All of Barnard's Milky Way photography was carried out with lenses rather than mirrors. Bernhard Schmidt did not invent the wide-angle reflecting telescope until 1932, after Barnard's death. At the present time, the best photographs of large Milky Way regions are being obtained with either Schmidt or Maksutov-type reflectors. The Palomar Schmidt telescope has a 48-inch correcting plate and a spherical mirror 72 inches in diameter. A 32-inch Schmidt instrument is at Bergedorf Observatory, near Hamburg, West Germany. Several large Maksutov telescopes are operating in the Soviet Union, for example at the Crimean Astrophysical Observatory and at Burakan Observatory in Armenia, and excellent photographs have been taken with them. Recent experiments seem to indicate that the optical performance of the Schmidt telescope is somewhat better than that of the Maksutov, but both types are excellent for covering sky fields of the order of 20 degrees across. Small wide-angle optical systems developed by L. G. Henyey and J. L. Greenstein have recently proven very useful. Shown here is a typical Milky Way photograph taken with a Henyey-Greenstein camera, covering a region of the sky 140 degrees across.

Barnard was primarily interested in the shapes of the dark cosmic clouds. Max Wolf of Heidelberg, who also contributed significantly to astronomical photography, invented a statistical method to obtain crude estimates of the distances and opacities of different dark nebulae. Later investigators found that starlight passing through obscuring clouds is appreciably reddened (which indicates that the interstellar particles in the clouds have sizes of the order of 1/100,000 centimeter) and that the transmitted starlight is often partly polarized.

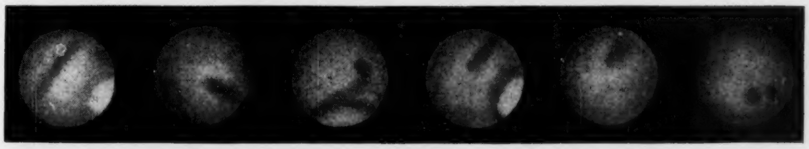
Stars happening to lie near a dark cosmic cloud may illuminate parts of it, thereby producing reflection nebulae whose spectra resemble the stars'. A reflection nebula lit by a *B*-type star is strongly blue, whereas the dense cosmic cloud near Antares is almost as red as Antares itself. The nebula surrounding the Pleiades stars was the first one to be recognized as of the reflection type, by V. M. Slipher at Lowell Observatory in 1912.

Although photographs of dark nebulae have been accumulating for 70 years, we still have no reliable information concerning the motions of these objects. But there is every reason to believe that we shall soon be able to detect displacements of the edges of certain dark clouds, and probably also the gradual fading of stars passing behind them, or the emergence of previously invisible objects. Long ago, attempts were made to explain certain types of stellar variability by such processes, but there is yet no definitely established case of a star whose brightness has been altered by changes in the opacity of the foreground material.

I am grateful to Mrs. V. Zebergs for her assistance in preparing this article.

Getting Acquainted with Astronomy

Jupiter's Satellites



Ganymede, Jupiter's third satellite, as seen in the 15-inch refractor of the Jarry-Desloges Observatory, on six nights between December 12, 1917, and February 13, 1918. Changing marks indicate that the moon rotates.

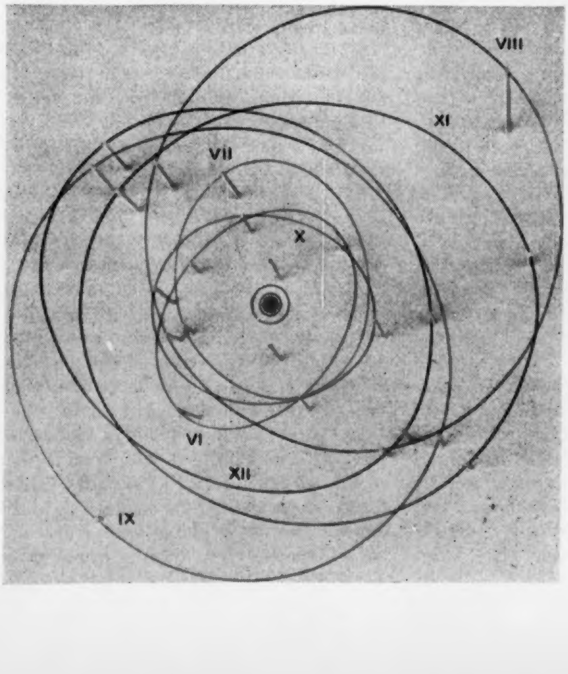
WITH a dozen known satellites, Jupiter is the center of a miniature solar system. No other planet has so numerous a retinue of secondaries (if we omit the tiny artificial bodies circling the earth and the host of moonlets that make up the Saturnian ring system). The runners-up are Saturn with its nine moons, and Uranus with five.

Jupiter's satellites are of two sharply contrasting kinds. Four of them are giant moons, comparable in size to the earth's satellite or to the planet Mercury, and are bright enough to be seen readily in binoculars. They were among the first objects discovered with the newly invented telescope in the winter of 1609-10, independently by Galileo in Italy and by Simon Marius in Germany. Recent historians have established that Marius was the first to note their existence, and the fact of their revolution around Jupiter, but Galileo had priority in recognizing the fourth satellite. Together, these bodies are often referred to as the Galilean satellites; individually, they are designated **I, II, III,** and **IV,** in the order of increasing distance from the planet. The corresponding names, Io, Europa, Ganymede, and Callisto, were introduced by Marius.

The remaining eight satellites are small and very faint. With the 36-inch Lick refractor in 1892, E. E. Barnard discovered **V**, a little point of light even closer to Jupiter than **I**, orbiting in only 11 hours 57 minutes. Because of the overwhelming glare of the planet, this difficult object is observable only in very large telescopes. Satellites **VI** to **XII** are faint moons moving far outside the others, and were discovered photographically between 1904 and 1951. Their magnitudes range from 14 to 18. Remarkably, four of them (**VIII, IX, XI,** and **XII**) are moving around Jupiter in the opposite direction from all the others. The outer satellites are so remote from the planet that their motions are subject to large disturbances from the sun's attraction, posing difficult problems for specialists in celestial mechanics.

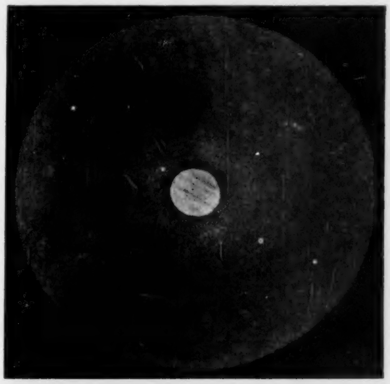
The four Galilean satellites, on the other hand, present a variety of interesting phenomena for amateur observers. Because of their relative proximity to Jupiter, **I, II,** and **III** on every revolution pass in front of the planet's disk, behind it, and through the Jovian shadow cone. In addition, the shadows of the satellites themselves move across the disk. But **IV,** in its larger orbit, shows these phenomena only during about five years out of every 12, at other times passing north or south of the disk and shadow cone.

For a specific illustration, consider the events of **I** during the first days of July. This is before the planet's opposition (July 25th); hence, the shadow cone of Jupiter extends to the west of its disk in the sky, as the chart on page 55 indicates. On July 1st at 5 o'clock Universal time, **I** is in the farther half of its orbit, slightly west of the disk and approaching it. At 5:20, the moon disappears into eclipse. Because of the appreciable size of the satellite, it takes about two minutes to fade from bright 6th magnitude to invisibility — a striking sight!



This model of the orbits of Jupiter's 12 satellites, made by Owen Gingerich, is viewed from a point above the planet's pole. The paths of the inner moons are drawn on a sheet of plastic, and those of the outer satellites are of brass wire supported by dowels. The actual orbits of the outer satellites change considerably from one revolution to the next, because of large perturbations by the sun.

Io's exit from the shadow will be unobservable, taking place behind Jupiter. This moon next becomes visible at 8:13, as it emerges from occultation at the planet's east limb. In the United States, all of the foregoing events occur during the hours of darkness on the night of June 30-July 1, the correction from Universal time to standard time being five hours for East Coast observers and eight hours for those on the West Coast.



Jupiter and its four Galilean satellites, as they appear in a small telescope. From "Astronomie," by L. Rudaux and G. de Vaucouleurs.

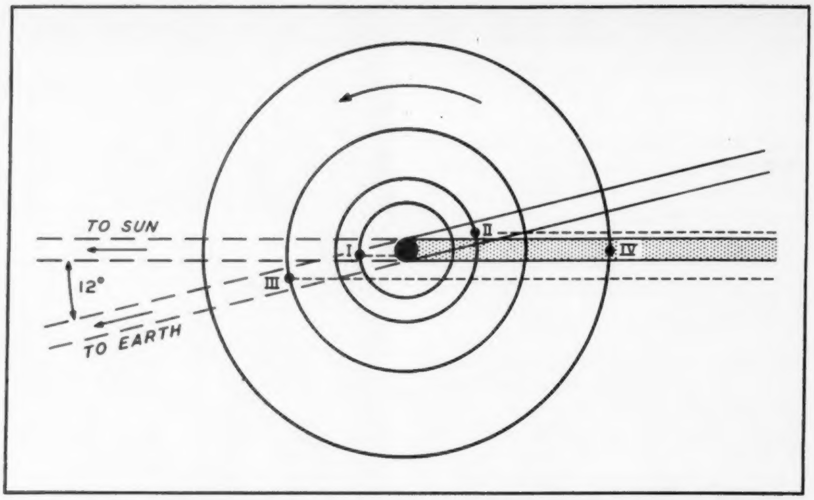
During the following hours, **I** moves out to eastern elongation from Jupiter, then approaches the disk again while traversing the nearer half of its orbit. On the 2nd at 2:28 UT, the shadow of **I** enters upon the eastern edge of the disk, followed by the satellite itself 34 minutes later. In a telescope, the shadow appears as a very small, very black dot, and the moon as a tiny light disk. They travel westward together across Jupiter's face, leaving it at 4:46 and 5:20, respectively. Thereafter, Io travels out to western elongation, then swings back to enter eclipse again at 23:49 UT, July 2nd. The whole cycle has taken 1 day 18 hours 29 minutes — the synodic period of **I**.

The pattern just described is typical of **I** and **II** before Jupiter has reached opposition. After opposition, the planet's shadow is displaced eastward of the disk. This changes the sequence of events to the following: beginning of occultation at the west limb, reappearance from eclipse east of the planet, eastern elongation, beginning of satellite transit, beginning of shadow transit, end of transit, and

end of shadow transit. At the time of opposition, Jupiter's shadow is concealed behind the disk, so for a few days eclipses will be practically unobservable.

An additional possibility arises for Ganymede and Callisto when Jupiter is several months from opposition, and its shadow cone has a considerable eastward or westward shift. Under these circumstances, both the beginning and end of an eclipse or occultation can be observed. For example, in August this year, **IV** undergoes occultation from 21:00 on the 24th to 1:28 on the 25th, and is visible on the east side of the planet until eclipse from 3:45 to 8:18.

Predictions of these events are published yearly in the *American Ephemeris* (on pages 344 to 365 of the volume for 1961). The predicted times are only rough approximations, and sometimes differ by several minutes from observation. Certain rare events, such as the eclipse of one satellite by another, are not listed there, but are forecast in the *Handbook* of the British Astronomical Association (see page 32 of this issue).



Some of the phenomena presented by Jupiter's satellites are shown in this diagram for a time when Jupiter is near western quadrature to the sun. From the earth, III would be seen passing in front of the planet (in transit). Both I and its shadow, indicated by the dashed line, are also in transit. II is occulted by Jupiter, while IV is eclipsed by the planet's shadow.

Easiest of all satellite phenomena to observe are the eclipses, for which a 3-inch refractor serves well. Timings of these events can be recorded to 0.1 minute, noting the last speck of light at a disappearance, or the first speck at a reappearance. Because of the slower motions of **III** and especially **IV**, their light changes are more gradual, making first or last visibility more uncertain than for **I** or **II**. Since the threshold of visibility depends on many factors, eclipse timings must always include a record of the instrument used and sky conditions.

Satellites X and XI, photographed with the 100-inch telescope by Seth B. Nicholson. The lower pair is from the discovery plates of XI, taken on July 30, 1938, exposure 60 minutes. The satellite's motion is shown by its change in position among the stars in the field. Mount Wilson and Palomar Observatories photographs.

Transits of satellites across the disk of Jupiter require, as a rule, larger instruments for satisfactory viewing. Since the edge of Jupiter is appreciably darker than its center, a satellite usually appears lighter than the planetary background just after entry, and may look darker than the background during mid-transit. High powers and good seeing are desirable for watching shadow transits. When the shadow is just entering or leaving the disk, it appears greatly distorted against the curved surface of the planet.

In 1961, the orbits of the Galilean satellites are presented nearly edgewise to the earth, and a transiting or occulted satellite moves along the planet's equator. This makes possible a fairly accurate evaluation of the equatorial diameter of Jupiter by timing the duration of an occultation or transit. Suppose a transit of **I** is found to last 138 minutes, or 0.0541 of the synodic period of 2,549 minutes. Multiplying this fraction by the circumference of the orbit, 1,648,000 miles, gives 89,200 miles for Jupiter's diameter.

For the convenience of amateurs wishing to try this method, the circumferences of the other satellite orbits are: **II**, 2,621,000 miles; **III**, 4,181,000; and **IV**, 7,355,000. The corresponding synodic periods are: **II**, 5,118 minutes; **III**, 10,320; **IV**, 24,125.

If enough optical power is employed to show the satellite's disk clearly, it is possible to time the interval between external and internal tangency of its disk and Jupiter's. Then the same kind of calculation can be made for the diameter of the satellite.

The angular diameters of the Galilean satellites are, according to E. E. Barnard's micrometer measurements with the Yerkes 40-inch telescope: **I**, 1.05 second of arc; **II**, 0.85; **III**, 1.51; and **IV**, 1.43. The disk of the largest moon, Ganymede, can be made out with a 4-inch telescope under very favorable conditions. R. T. A. Innes, who made regular observations of these satellites from 1908 to 1925 with a 9-inch refractor in South Africa, reported that 700x would always show him the disks, but that this was not the case with 400x. On many occasions, a satellite entering eclipse appeared dichotomized, that is, like a tiny quarter moon.

Surface features on the satellite disks can be usefully observed only with very large apertures. Barnard with the 36-inch Lick refractor at 1,000x found that **I** has a bright equatorial belt and dark polar caps, while **III** and **IV** have bright polar caps and conspicuous though vaguely shaped dusky markings. The easiest of these features is **III**'s bright cap, which has been definitely seen with a 12-inch telescope.

The rotation of these mottled disks produces small brightness variations which, according to J. Stebbins' photoelectric measurements in 1926-27, amount to 0.21, 0.30, 0.16, and 0.10 magnitude, for satellites **I** to **IV**, respectively. In each case, the period of light change is equal to that of orbital revolution. Thus each of these bodies always keeps the same face turned toward Jupiter, in the same way that our moon behaves relative to its primary, the earth.

LETTERS

Sir:

During the February elongation of Mercury, I saw that planet with the naked eye on seven consecutive dates, from the 6th to the 12th. Altogether, this makes 57 days in the last 10 years on which I have seen Mercury with the naked eye or a telescope.

This record attests to the transparency of the New Mexico atmosphere. All observations have been made at Alamogordo or the neighboring Air Force Missile Development Center. On any good night stars are visible to magnitude 6.2, and to 6.4 when conditions are exceptional. I have observed Uranus with the naked eye on four evenings.

Venus has been seen 11 times by daylight, the latest sightings being on February 19th, 21st, and 23rd. Most of the navigational stars and bright planets can be viewed by day with standard 20x theodolites of 1¼-inch aperture.

BERNARD D. GILDENBERG
901 Cauthen Lane
Alamogordo, N. M.

Sir:

Recently, Otto Struve described some of my work on radio source Cygnus A for the readers of Sky and Telescope (November, 1960, page 259), and in a subsequent letter R. Minkowski described his views on the subject (January, 1961, page 23). My paper, "Radio Galaxies," was circulated in the Soviet Union in the middle of January, and an English translation of it is being published in the current issue of *Soviet Astronomy — AJ*.

In it I emphasize that Cygnus A is most likely a double galaxy with the nuclei forming a very close pair, and that the components are genetically related. As another, but much less likely possibility, I consider the hypothesis that Cygnus A represents a single galaxy crossed by a broad dark band, similar to NGC 5128, which is identified with Centaurus A. Although I advanced this hypothesis as early as 1953, I had myself long since felt it to be improbable, and Dr. Minkowski has argued strongly against it.

Cygnus A and Centaurus A are similar, I believe, not merely in the resemblance between their associated optical objects, but in having analogous radio structures. Each has two radio-emitting regions, located symmetrically on opposite sides of the galaxies observed optically. These radio-emitting clouds are highly unstable formations, for there is no force in nature that can prevent them from expanding indefinitely. Their surface intensities are, therefore, diminishing.

Extrapolating backward in time for Centaurus A, we find that its radio luminosity was once thousands of times as great as now, and its brightness tens of thousands of times. Some hundreds of millions of years ago, it was a "twin" to Cygnus A as the latter radio source appears now.

It has recently been found that the extended source of small angular size associated with the dark band in NGC 5128 is double, with the line joining the two centers lying within the band. Possibly this effect of doubleness arises from an edge-on view, with an absence of radio emission at the center of the system. The latter situation could be due to a high density of interstellar gas, which would rapidly destroy relativistic particles that produce radio emission by the synchrotron mechanism. A similar phenomenon may perhaps occur in the nucleus of our own galaxy.

In my paper, I advance a number of arguments against the colliding-galaxy idea, none of which Dr. Minkowski has effectively refuted. A number of astronomers now working in this field either categorically reject the collision hypothesis (V. A. Ambartsumian opposed it even earlier than I) or consider that it is by no means the only permissible one. Instead, the nature of radio galaxies seems intimately connected with the origin and evolution of optical galaxies.

In the early "halo" stage of the formation of a galaxy, Type I supernovae must occur frequently, an immense number of relativistic particles being formed in a relatively short time as by-products of the nucleogenetic process. Objects such as Centaurus A and, especially, Cygnus A must be relatively young. Yet most radio galaxies appear to be stable objects. This means that the relativistic particles occupy a rather considerable volume around each such galaxy and do not dissipate indefinitely out into extragalactic space.

The relativistic electrons are here formed through collisions of very fast heavy particles with interstellar gas nuclei. Since these processes occur quite slowly, the intense radio emission of a young galaxy may persist over billions of years. In this event, the radio power is not determined by the "instantaneous" frequency of supernova outbursts in a given galaxy, but by their frequency early in its history.

We still do not know whether the formation of jets — radio-emitting clouds consisting of relativistic particles, magnetic fields, and gas — is a peculiarity of such powerful objects as Cygnus A, Centaurus A, and a few others, or whether it occurs in practically every young galaxy. At any rate, some of the very fast particles produced during nucleogenesis, perhaps even the majority, are not released to extragalactic space.

Furthermore, what has become of the relativistic particles formed during nucleogenesis in our own galaxy? There are reasons to suppose that they were once hundreds of times as abundant as now. Most likely they have been destroyed in nuclear collisions; our stellar system is quite old, and there has been enough time for this. A state of equilibrium now prevails, with the Milky Way's radio power being determined by the "instantaneous" frequency and power of supernovae. Perhaps this condition indicates that our galaxy is normal with regard to its radio power.

The foregoing illustrates my belief that the problem of the radio galaxies is closely interwoven with those of cosmogony and cosmology. The radio-emitting power of any galaxy seems to be governed by fundamental laws inherent in its evolution.

I. S. SHKLOVSKY
Sternberg Astronomical Institute
Moscow, U. S. S. R.

ED. NOTE: The foregoing is a condensed translation of Dr. Shklovsky's letter, which was written in Russian. The pertinent thoughts of the original have been preserved, but some of the technical details of the discussion have been omitted as they are more suited to direct correspondence among the scientists concerned.

Sir:

I have come upon a vivid account of a "wonderful display" of the aurora borealis, seen from near Rochester, New York, on September 22 and 23, 1827. Can some reader furnish me with other reports of this occurrence?

RUTH SHINSEL
1610 M Ave.
La Grande, Ore.

Sir:

The Ceylon Astronomical Association was founded in June, 1959, and we now have 56 active members. Our journal, *Equatorial*, first appeared last October. Its name is based on the fact that Colombo is only seven degrees north of the equator.

Under the direction of E. E. Vezey, formerly of Texas Agricultural and Mechanical Arts College, several members of our society have been grinding mirrors at home. I recently completed a 10-inch Newtonian reflector, and two others finished 8½-inch instruments. The chief difficulty in telescope making in this country is obtaining glass of the necessary thickness.

Ceylon has several small observatories; two of them own mirrors by the former director of Armagh Observatory, Reverend William F. A. Ellison. A 12½-inch mirror made by him is in the observatory at Kandy, the historic hill capital of Ceylon, and Colombo possesses a 13-inch reflector.

Since we are quite new to astronomy, we would like to start corresponding with more experienced amateurs and groups around the world, in order to exchange ideas and techniques.

D. S. HERSCHEL GUNAWARDENA
31/5 Castle St.
Colombo, Ceylon

Johann Kepler and the Laws of Planetary Motion

RUFUS SUTER

IF YOU stick two tacks through a sheet of paper, tie a thread loosely around them, and, with a pencil holding the thread loop taut, trace the resulting curve, you will draw an ellipse with the tacks as its foci.

Kepler's first law of planetary motion states that a planet travels in an ellipse with the sun at one of the foci. The publication of this law in 1609 marked a very important advance in astronomy. All of Kepler's predecessors – whether like Ptolemy they believed the heavenly bodies to move around the earth, or like Copernicus to move around the sun – held that celestial bodies swung in perfect circles. Even Galileo seems to have regarded Kepler's ellipses as visionary nonsense. But Kepler found from Tycho Brahe's observed positions of Mars that its orbit was in fact an ellipse, and this led him to state his first law.

Another ancient prejudice, that each planet moves at an unvarying speed in its orbit, was refuted by Kepler's second law, also announced in 1609. According to this principle, the radius vector of a planet (the line joining it to the sun) sweeps over equal areas in equal intervals of time. In the diagram, the shaded areas are all equal; hence the planet requires the same length of time to move from **A** to **B** in its orbit as it does from **C** to **D**, or from **E** to **F**. Thus it travels fastest when nearest the sun (at perihelion), and slowest when farthest from the sun (aphelion).

In this second law, Kepler made a major innovation. Previous astronomers had treated the apparent motions of the heavenly bodies as a problem of geometric perspective. Kepler's approach was in a sense that of an engineer rather than a geometer. While he was interested in the purely geometric aspects of planetary motions, he also pondered the mechanical causes of these motions. Consideration of

Johann Kepler (1571-1630) inherited the observations of Tycho Brahe, and from them derived his laws of planetary motion. Kepler's search for cosmological patterns inspired Paul Hindemith's recent opera, "Die Harmonie der Welt."

how the planets should move if there were a center of power in the sun gave him his first inkling that each planet travels faster when nearer the cause of its motion. In the older approach, it was possible for an astronomer to deny that he asserted anything about the *real* movements of the heavenly bodies when he adopted the Copernican or heliocentric hypothesis. He was merely choosing one of several sets of geometrical patterns for simplicity in calculation or for subjective aesthetic reasons. This expedient became quite popular among scientists when the issue of the heliocentric theory versus theological authority arose. Kepler, with his dynamical point of view, could no more use it than could an engineer in a later age believe that a wheel connected to a steam engine by a belt made the engine run, rather than vice versa.

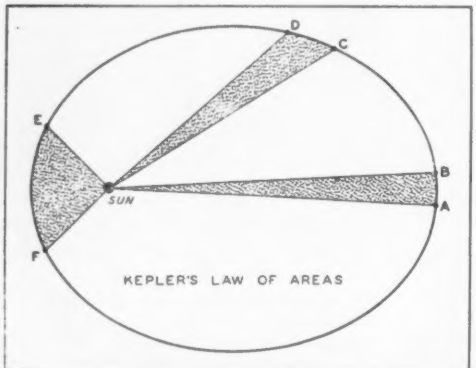
Kepler's third law, announced in 1619, is a relation between the revolution times of the planets and the sizes of their orbits. It states that the ratio of the squares of the periods of any two planets is the same as the ratio of the cubes of their mean distances from the sun. In other words, with the earth's year and distance from the sun as units, the period squared for any planet is equal to its distance cubed. Thus, one moving in a circular orbit at four times the earth's distance from the sun would have a period equal to the square root of 4^3, or eight years.

These three laws made possible much better predictions of planetary positions and eclipses of the sun and moon. They could be used for drawing up accurate ephemerides, and for fixing dates in ancient history. Later in the 17th century, Newton's law of gravitation, from which Kepler's laws are deducible, gave a rational and unifying explanation of them. It could then be seen that Kepler's laws are actually close approximations, which would be exact if the masses of the planets were negligible compared to the sun's.

Some of Kepler's contemporaries, among them Galileo, were seeking a physical proof for the theories of the earth's motion and the central position of the sun. Few at that time recognized it in the Keplerian laws. Nevertheless, from our hindsight we can see today that the proof was there.

There is no need to detail here how meticulously Kepler checked his rules against the observations of Tycho Brahe, whom he had served as an assistant before succeeding him as imperial mathematician at Prague. He was fully aware of the importance of empirical or observational

(Continued on page 25)



Left: The equal shaded areas indicate that a planet would move from A to B in the same amount of time as from C to D, or E to F.

Right: The table shows that for each planet the distance from the sun, cubed, is equal to the period squared, in agreement with Kepler's third law.

KEPLER'S HARMONIC LAW

Planet	*Distance A. U.*	*Period Years*	*Distance Cubed*	*Period Squared*
Mercury	0.387	0.241	0.058	0.058
Venus	0.723	0.615	0.378	0.378
Earth	1.000	1.000	1.000	1.000
Mars	1.524	1.881	3.54	3.54
Jupiter	5.20	11.86	141	141
Saturn	9.54	29.46	868	868
Uranus	19.18	84.01	7,060	7,060
Neptune	30.06	164.79	27,160	27,160
Pluto	39.52	248.43	61,720	61,720

OBSERVING THE SATELLITES

Man in Space

AMERICA'S space effort passed another milestone with the suborbital downrange ride of Comdr. Alan B. Shepard, Jr., in a Mercury capsule on May 5th. The flight of "Freedom 7" lasted only 15 minutes from its take-off at 14:34:13 Universal time from Launch Complex Five at Cape Canaveral, Florida, to its splashdown near latitude 27° north, longitude 76° west, in the Atlantic Ocean. During the flight, which attained a height of 117 miles and a range of 302 miles, the 2,250-pound package reached a top speed of 5,160 miles an hour, relative to a nonrotating earth.

Primarily, this test shot was intended to study the astronaut's reactions, and secondarily to check the fitness of the capsule. Shepard's physiological responses and ability to perform certain tasks had been evaluated under laboratory conditions prior to the flight. Thus his performance in the actual mission would show how reliable these tests were, and how effectively they prepared a man for the real experience. Early reports state that Shepard's flight has validated the testing and training procedures. The National Aeronautics and Space Administration claims that the Shepard flight was the first in which the pilot assumed control of the orientation of his spaceship.

The booster for this Mercury ascent was a Chrysler-built Redstone missile. An earlier version had been used as the first stage of the Jupiter-C that placed Explorer I in orbit for America's first successful satellite launching. The enlarged Redstone is about six feet in diameter, and with its manned capsule and escape tower has an over-all height of 83 feet. The total lift-off weight is 66,000 pounds, and the initial thrust amounts to 78,000 pounds.

Among the many safety features in Project Mercury equipment is a special system designed to end a mission by pulling the capsule away from sudden trouble. If the direction or amount of the rocket's thrust is wrong, or if, for example, electrical power is lost, this emergency system notes the fact automatically. When this happens, or if the ground station or pilot senses trouble, the booster's thrust is terminated, the spacecraft is separated, and the escape rocket mounted on trusswork atop the capsule fires to lift the capsule at least 2,000 feet clear of the booster.

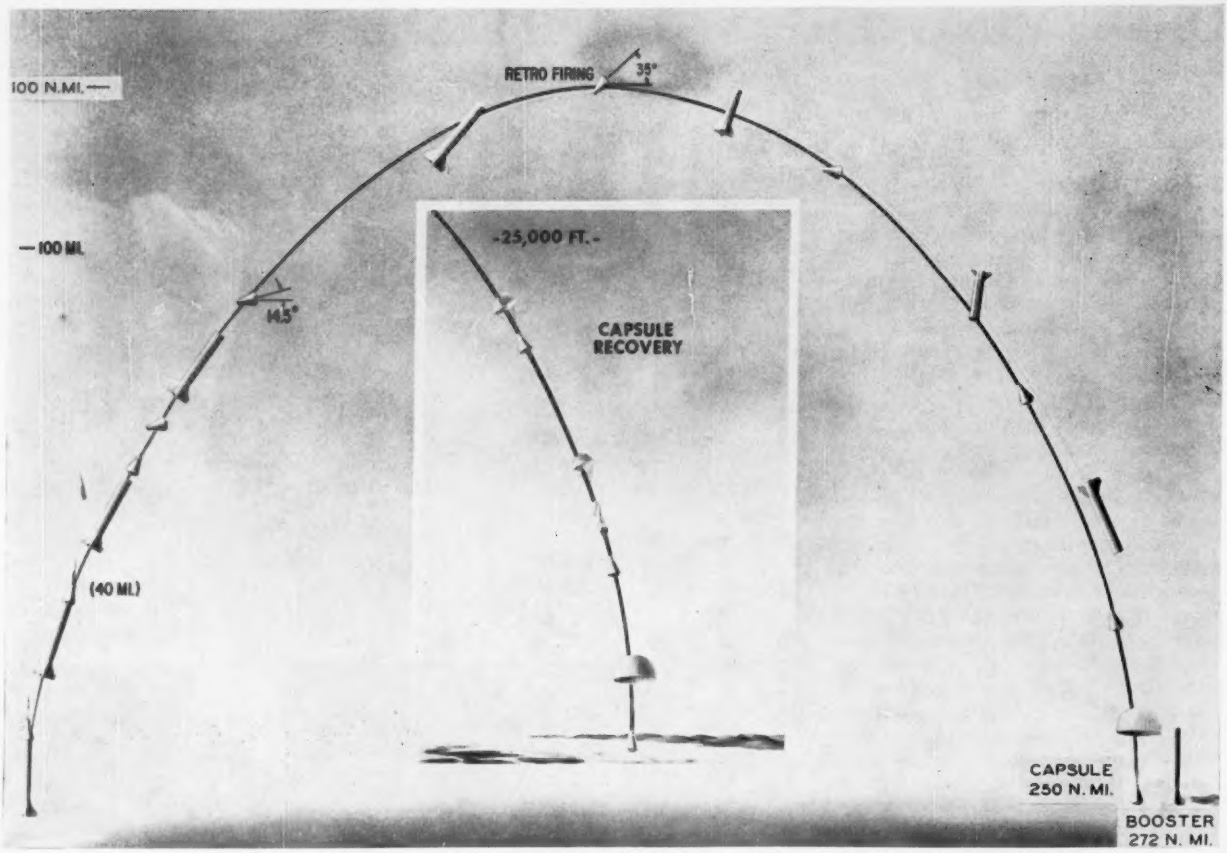
The complex design of the Mercury capsule is the result of more than two years of intensive development by McDonnell Aircraft Corp. engineers. Several thousand subcontractors and suppliers have also contributed to the high-priority project. Much of the capsule's hardware had to be redesigned to meet both the severe weight limitations imposed by available boosters, and the need to assure the astronaut's safety.

Outwardly, the capsule's appearance has changed little during development: a truncated cone (the cabin) is capped by a short parachute canister, and this in turn is topped by another truncated cone that serves as an antenna cover. Only nine feet tall, the capsule is 74 inches in diameter at its blunt end. Yet this small package contains an environment for the passenger's survival, with an alternative system should any component fail. The main systems are entirely automatic, while the emergency ones are either automatic, activated by ground command, or controlled by the astronaut.

The construction of the cabin walls illustrates some of the problems that faced the designers. The pressure-tight inner vessel is made from two very thin layers of titanium, the outer of these corrugated for strength. Welding this assembly required the development of a new technique. To the outside of the pressure vessel was welded a framework of titanium stringers, and the whole was carefully insulated to break the flow of heat to the cabin's interior. Then an overcoat of corrugated metal was fastened to the stringers, in order to withstand the heat and stress of re-entry. In Shepard's flight, the exterior layer used beryllium shingles, and a massive beryllium heat shield covered the skin at the blunt end. In aerodynamic flight, this end swings forward, regardless of the initial orientation, and takes the brunt of the heat impact. In later missions, an ablative shield will be used, whose vaporization at re-entry will cool the remaining structure.

A primary automatic control system serves to regulate the spatial orientation of the capsule during its orbital flight, as well as just before the retro-rockets fire, and during the final plunge into the atmosphere. Deviations from the desired orientation are detected by infrared sensors and gyros, and are corrected by hydrogen peroxide jets. In another mode of operation, the pilot can assume con-

Comdr. Alan B. Shepard, Jr., on the aircraft carrier U. S. S. Champlain, stands in front of the Mercury capsule that carried him to an altitude of 117 miles. The capsule's landing cushion, between cabin and heat shield, is held partly open by blocks behind Shepard's feet. NASA photograph.



The flight sequence of a Redstone rocket and its Mercury capsule is indicated in this National Aeronautics and Space Administration diagram of an early flight plan. Heights and distances are given in statute and nautical miles; 100 nautical miles equal 115 statute. After the Redstone booster ceases firing, the superstructure atop the rocket blasts away. This is a safety system which can pull the capsule away from the Redstone in case of emergency. The capsule then separates; its orientation and the rocket's are shown for the remainder of the flight.

trol in either of two ways. In one, his control stick transmits electrical signals to six of the 18 peroxide jets; in the other, the same stick mechanically actuates throttle valves in the thrust system.

The control stick is in the pilot's right hand as he sits strapped in his contour couch against the blunt wall of the cabin. Pressure around him is maintained with oxygen at five pounds per square inch. Should cabin pressure be lost, his suit will automatically inflate to this pressure. Carbon dioxide removal and humidity control are automatic.

During Shepard's flight, duplicate communications channels were provided and tested. Periodically he radioed to flight monitors reports which included the voltage of the battery power supply, the amount of hydrogen peroxide fuel remaining, the oxygen pressure in the cabin, the accelerative stress, and other details.

The maximum acceleration during Shepard's launching amounted to six times gravity, and then for $4\frac{3}{4}$ minutes he experienced weightlessness. While the retro-rockets were not needed to initiate re-entry during this suborbital flight, they were tested, and found to develop 0.05 times gravity. (From orbital motion at 17,500 miles per hour, only a two-percent reduction in speed would be needed to cause re-entry.) Then, during downward return through the atmosphere, the acceleration mounted toward 11*g*, but the total time it exceeded 5*g* was only about half a minute.

The only reported malfunction during Shepard's flight was failure of a green signal light to show that the retro-rocket package had been jettisoned after firing. He pressed an override button that could release this package, and then the light came on, to signify that the event had already occurred on schedule.

One test planned was the recognition of geographical features with the periscope display on the instrument panel. These were seen, together with cloud cover. Later, the astronaut closed his eyes and touched many preselected controls on the complex instrument panel before him, in order to test his psychomotor reactions. Throughout the flight, cameras monitored the entire instrument board, as well as Shepard's actions and appearance.

The success of the May 5th experiment means that manned orbital flight in a Mercury capsule now awaits only improved performance of the Atlas booster. Meanwhile, additional suborbital Redstone flights by astronauts are scheduled.

Previously, the Atlas had been used four times in the Mercury program. On September 9, 1959, a Big Joe Atlas successfully sent up a "boilerplate" capsule, in order to test re-entry performance and recovery techniques. Next, on July 29, 1960, the Mercury-Atlas 1 (MA-1) test failed, due to booster malfunction. Later, on February 21st of this year, MA-2 successfully tested the capsule, but on April 25th MA-3 was blown up by the range safety officer when the booster did not perform as intended.

If we also count earlier satellite launchings, Atlas has already been applied 13 times, 12 of these with superstructures attached. In the latter firings, only four missions have been completely successful, though very few of the failures were catastrophic malfunctions. Attachment of the Mercury to the Atlas will be further tested before a manned launching.

The main objective of the Mercury program is to carry a man three times around Earth and land him safely. Modified capsules are being developed for longer-duration animal flights, mainly to study improvements in the life-support systems. At the same time, the U. S. Air Force is developing Dyna-Soar, a 5-ton

delta-wing glider that will attempt to carry a man into orbit atop a Titan II rocket. The winged design is expected to give better control over re-entry heating than the ballistic-parachute system of Mercury does.

Advances in manned space exploration beyond Mercury and Dyna-Soar are sure to be very costly. Recently, Congress has been asked to increase NASA's funding for the fiscal year 1962 to $1,784,300,000. Much of the increase is earmarked for Apollo, which is a successor program to the man-in-space effort, and for expanded research in biological problems related to space travel. Project Saturn, which will supply the booster for Apollo flights, already was the biggest item in NASA's budget.

Large as these funds for 1962 are, they are small compared to the projected cost in years ahead. Annual expenditures in excess of four billion dollars will be asked, and some 40 billion may be required before the first U.S. expedition sets foot on the moon. So great is the effort required for this development that it may be said that the only component now nearly ready to go is man himself.

Vostok Flight Records

THE Fédération Aeronautique Internationale, with headquarters in Paris, France, has established rules under which world records of various kinds may be claimed for manned spaceflights. Immediately after Yuri Gagarin's 108-minute journey in Vostok on April 12th, claims were filed for duration, altitude (203 miles), and total load (4,725 kilograms) — all in the class of manned orbital flights.

Nearly seven weeks after the event, certain facts required by the rules for substantiation of the claims were submitted to the federation, and thus made public for the first time. According to unofficial translations of Tass reports, Vostok was launched by a rocket with six engines. The trip began at Baikonur, near the Aral Sea, at latitude 47° north, longitude 65° east, and is said to have ended near the village of Smelovka, Ternov district, Saratov region.

These locations confirm the deductions cited on page 330 of last month's issue for the beginning and end points of the flight.

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

CORRECTIONS

On page 330 of the June issue, first paragraph, the longitude at which Vostok passed northward over the equator should read 15° east, not 15° west. This error was noted by Paul K. Hoover, Salt Lake City, Utah.

On page 331, the right-hand picture of Explorer XI's gamma-ray telescope is inverted.

Astronomers Discuss Project West Ford

TO provide reliable intercontinental radio communications, W. E. Morrow, Jr., of Lincoln Laboratory, has proposed placing into orbit around the earth a belt of numerous tiny metallic needles. Already plans have been made to launch a test belt of such dipoles, 75 pounds of them to be dispensed from an artificial satellite to form a cloud that will have spread completely around the earth after a month. This program, now known as Project West Ford, was briefly described in SKY AND TELESCOPE, December, 1960, page 329.

The question of whether West Ford belts will interfere with astronomical observations has aroused much discussion, and four articles in the April *Astronomical Journal* deal with this problem. Dr. Morrow and D. C. MacLellan report on some of the properties of the proposed belts. The first test belt, they predict, should cause quite limited sky brightening and its effect on radio astronomy measurements would be very small. However, later West Ford belts may contain much larger quantities of the tiny needles.

William Liller of Harvard Observatory points out, "Optical astronomers must carefully evaluate the effects of the orbiting dipoles in the test belt as accurately and as quickly as possible so that an upper limit can be set on the size of future experiments, if any." He recommends photographic observations with fast, wide-field cameras to record the belt, which during its first two months aloft would appear as a very faint, narrow, luminous streak spanning the sky. In addition to photoelectric and polarimetric studies, he stresses the value of visual observations, for example naked-eye sightings through a slowly rotated sheet of polaroid.

Calculations by A. E. Lilley of Harvard confirm the Morrow-MacLellan appraisal that the test belt will have negligible effects on broad-band radio astronomy observations, but there may be disturbances to radio spectrum-line studies. Later operational belts, densely sown with dipoles, will create unavoidable problems for radio astronomers. Dr. Lilley adds the following broader comment:

"The threat to the conduct of radio astronomical research by orbiting media should be viewed in perspective with other sources of man-made interference. New communications and navigation systems employing powerful transmitters in earth satellites will be soon forthcoming. These technological advances pose another source of severe interference to radio research. The pursuit of basic science and the progress of space radio technology represent needs of man which must be advanced. For the impending interference a simple solution exists: allocation of clear frequency bands for basic science. This action is imperative and must ultimately rest on national and international agreements."

OBSERVING TIME ON KITT PEAK

The national observatory on Kitt Peak in southern Arizona was established to provide American astronomers with modern observing instruments. The director, N. U. Mayall, has announced a policy allocating about 60 per cent of the observing time to visiting astronomers and qualified graduate students.

To supplement the 36- and 16-inch reflectors currently operating on the mountain, observatory headquarters in Tucson contain laboratory equipment that includes a digital computer, a microphotometer, measuring engines, and a spectrocomparator. Additional information is available from Kitt Peak National Observatory, 950 N. Cherry Ave., Tucson, Ariz.

JOHANN KEPLER AND THE LAWS OF PLANETARY MOTION

(Continued from page 22)

proof in astronomy. But there was another side to Kepler, more difficult for us in the 20th century to understand.

He was a metaphysician and mystic, whose mind was filled with the lore of Plato, Pythagoras, and Plotinus. Thus, while he laid the foundations of celestial mechanics, all his life he was entranced by the hope of finding a relationship between distances of the planets from each other and the ancient doctrine of the five regular solids. He tried to establish a connection between planetary orbits and the rules of musical harmony. Indeed, his passion for the harmony of the spheres probably first attracted him to astronomy and kept him there despite the practical difficulties of living in the midst of tremendous political and religious chaos.

A further aspect of Kepler's complex personality deserves mention. He was not eaten up by a passion to be the first to make a scientific discovery, and did not have the secretiveness characteristic of some brother astronomers. Instead, he sought co-operation among astronomers, for example in observing the total solar eclipse of October 12, 1605. In an age of religious controversy, he was without bigotry. Although a Lutheran, he sided with the Calvinists on some theological points, and at the same time remained on good terms with the Roman Catholics. When Jesuit missionaries at the court of the Son of Heaven in Peking failed to persuade Galileo to send them eclipse calculations, Kepler immediately supplied a part of the Rudolphine Tables which he was compiling. The fact was that Kepler's vision of the harmony of the universe raised him above the strife of his time.

Amateur Astronomers

An Active Amateur in St. Paul

DURING the past 25 years, I have devoted an increasing amount of time to studying and teaching astronomy. My first telescope, completed in 1937 when I was 14, initiated a succession of home-constructed instruments, and recently I built my Cobb Road Observatory.

Although today's trend is toward compactness, this observatory is a bit larger than originally planned. A dome 16 feet in diameter sits at one end of the 21-foot structure, leaving a rectangular area five by 16 feet for instrument storage, tables, and chairs.

The truncated-cone shape of the dome was chosen for simplicity of construction; ⅛-inch tempered Masonite was wrapped around the 1-by-4-inch frame ribs. It was covered with tar paper, with aluminum roofing paint for better heat reflection.

The dome does not turn on a track; it swivels on 32 roller-skate wheels mounted around the dome well on the observatory roof. Ten more wheels set horizontally on a flange around the outside of the well prevent the dome from slipping. So far I have turned it by hand, as the rolling friction is quite small, but I plan to install a crank or a motor. The observatory's interior is being finished in light blue, with the inside of the dome a flat black. There is ample wiring for red and white working lights.

At present the building is filled with all kinds of telescopic equipment. A 4¼-inch f/12 reflector has a 7-inch tube to give maximum side clearance for reducing thermal effects on the incoming light beam. This instrument splits the "double double" in Lyra very easily at a magnification of 250. An array of medium-sized reflectors includes a solar telescope with an unsilvered antireflection-coated 6-inch mirror, and 6-inch f/12 and 8-inch f/8 telescopes.

In the center of the observing area is my 125-pound, 12-inch off-axis reflector. Its 196-inch focal length gives a primary image of the moon 1¾ inches in diameter; low-power views promise to be excellent, as soon as astigmatic corrections are finished. Astronomical photography has always been one of my major interests, and in my equipment are three star cameras, between seven and 40 inches focus. The 12-inch telescope will be used for visual and photographic observation of the moon and planets.

About seven years ago I began teaching a night course in astronomy at Macalester College, and four years later took over the day course. This class's observation of the November 7, 1960, transit of Mercury was described in SKY AND TELESCOPE for January, 1961. Now in the process of expanding, the college is building a new science hall, with planetarium and observatory.

My profession, optometry, seems to be fading into the background as more time is spent on astronomical activities. Last January I began a series of 22 weekly half-hour local television presentations, entitled "Astronomy Today: A Guide to Other Worlds in Space." The programs emphasized the solar system, giving planetary facts and theories and observing hints.

The dome of the Cobb Road Observatory in St. Paul, Minnesota, has an opening five feet wide that allows the building to reach outside air temperature quickly, as well as providing an ample view of the sky for observing.

The local Moonwatch team, which I am currently leading, meets at the Cobb Road Observatory, and star parties take up the weekends. We prefer groups of about 25 persons, for each guest can then move freely about the building. However, one night 60 adults and cub scouts attended an open house, which was highlighted by a passage of Echo I over our area.

SHERMAN W. SCHULTZ, JR.
944 Cobb Rd.
St. Paul 12, Minn.

Just after evening fell on November 21, 1960, Sherman Schultz, Jr., took this photograph of his Cobb Road Observatory with a spectacular celestial backdrop. Over the doorway are the bright planets Venus (left) and Jupiter. Above them is the thin crescent moon, its night side faintly illuminated by sunlight reflected from the earth. This home-built St. Paul, Minnesota, observatory is a local center for the popularization of astronomy.

MIDDLE EAST CONVENTION

Members of the Astronomical League's Middle East region will convene at Hershey, Pennsylvania, on Saturday, August 19th. The meeting is being organized by the Astronomical Society of Harrisburg.

Lectures, exhibits, papers, and round-table discussions are scheduled to fill the day-long program, highlighted by the traditional banquet. Inquiries should be sent to Edward L. Naylor, 320 Wilhelm Rd., Harrisburg, Pa.

REPORT FROM ROCHESTER

IT WAS lilac festival weekend in Rochester, New York, when the Northeast region of the Astronomical League held its annual get-together. Although skies were cloudy on Friday evening, May 26th, more than 50 persons enjoyed the hospitality of the George Keenes and inspected their back-yard observatory (featured in the January, 1959, SKY AND TELESCOPE).

Saturday morning the delegates visited Bausch and Lomb Optical Co. to watch the pouring of optical glass. The first session at the Manger Hotel included papers on topics ranging from antique telescopes to activities of the Rochester Moonwatch team.

After lunch, Edgar Everhart, Mansfield Center, Connecticut, showed color slides of the September 17, 1960, solar halo display (January, 1961, issue, page 14). A feature of the eight-paper session was the exhibition of a clock giving standard and sidereal time, positions of the sun and moon, and lunar phases. This instrument was built by Edward Root of Rochester as a cloudy-weather project.

At the business session, Mrs. Margaret Tumiki, New London, Connecticut, was elected Northeast chairman, and Parker Atwood, East Haven, Connecticut, vice-chairman; Walter Wyman, Batavia, New York, was re-elected secretary, and Jack Welch, Springfield, Massachusetts, treasurer. Springfield was announced as the site for the 1962 convention, and the 1963 meeting is scheduled for Stratford, Connecticut.

Highlighting the banquet were solar-prominence movies filmed and narrated by Walter Semerau of Kenmore, New York.

AN AMATEUR OBSERVATORY IN THE TRANSVAAL

A successful star party marked the public opening of C. N. Williams' new observatory, located at Bedford View near Johannesburg, South Africa. Many amateur astronomers and friends from Johannesburg, Germiston, and Boksburg came to admire the observatory building and the well-constructed instrument it houses.

Dr. Williams' 5-inch refractor and its two finders are mounted equatorially on a short iron column bolted to a concrete block 16 inches in diameter. The telescopes are driven by a small synchronous motor.

The rectangular brick observatory has a sliding roof of corrugated steel, which moves on rails supported by piers on the building's south side. It is large enough to hold 20 people easily, and is fitted with a table, chairs, a library, and a radio receiver for time signals.

Dr. Williams was the team leader of the Johannesburg Moonwatch, which contributed many observations of early artificial satellites. He now plans to use his telescope for regular observation of the moon's surface features, a study for which his refractor is well suited and which has been neglected by many amateurs here in South Africa.

J. H. BOTHAM
94 Ascot Rd.
Judith's Paarl
Johannesburg, South Africa

LAKELAND, FLORIDA

Twenty-five amateurs, many formerly associated with other astronomical organizations, are members of the new Central Florida Astronomical Society. Adults and juniors interested in joining the group should contact Carson H. Sammons, 1810 Fredericksburg Ave., Lakeland, Fla., MU 2-3223.

SOCIETY LISTING

The October issue of SKY AND TELESCOPE is tentatively scheduled to carry Here and There with Amateurs, a listing of astronomical societies whose membership is open to the public. Any group that wishes to be included should send to this magazine by August 15th a post card stating: the organization's name, the city in which it is located, and the name, address, and telephone number of an official who can furnish details of the group's activities.

In addition, please answer the following questions by number:

1. Is the organization a member of the Astronomical League?
2. Does the society belong to the Western Amateur Astronomers?
3. Is there a junior section?
4. Is this an independent junior group?
5. Does the society include a subscription to SKY AND TELESCOPE as a privilege of membership?

To insure an up-to-date listing, each club should submit the post card promptly; otherwise the information published in the 1960 Here and There with Amateurs (October issue, page 209) will be repeated.

WESTCHESTER ASTRONOMERS LEAGUE

Thirty-five amateurs from all areas of Westchester County, New York, attended the first meeting of the Westchester Astronomers League. The gathering was addressed by Edgar Paulton, past president of the Amateur Astronomers Association of New York, and by Frank L. Aime, who gave an illustrated lecture on the home-made observatory and 16-inch Cassegrainian telescope that he built. The new group will meet regularly at the Hudson River Museum in Trevor Park, North Yonkers, on the third Friday of each month at 8 p.m. All are welcome.

VICTOR F. VOLK
749 North Broadway
Hastings-on-Hudson, N. Y.

THIS MONTH'S PROGRAMS AND CONVENTIONS

Detroit, Mich.: Astronomical League, Henrose Hotel. July 1-3.

New Orleans, La.: Pontchartrain Astronomy Society, 8 p.m., Metairie playground auditorium. July 7, M. O. Guidry, Texaco, Inc., "Use of Setting Circles," and Richard Sarradet, De La Salle High School, "Generalities of the Electromagnetic Spectrum."

Shreveport, La.: Shreveport Junior Astronomical Society, 7:30 p.m., Centenary College science hall. July 15, Ted Gangl, Texas Astronomical Society, "The Sky Is Not the Limit."

STELLAFANE MEETING

The 27th Stellafane convention will be held August 12th, on Breezy Hill at Springfield, Vermont. This first Saturday after new moon in August was chosen by popular vote of the 100 hardy amateurs who gathered under the big tent during the torrential downpour that washed out last year's meeting.

Edgar Everhart of Mansfield Center, Connecticut, is to be master of ceremonies for the program, which includes a workshop session on mirror polishing and figuring, a meeting of the Maksutov Club, the regular telescope contest, and observing. Twilight talks will include "Deep-Sky Wonders," by Walter Scott Houston, Henry Specht's "Photographic Measurements of Variable Stars," and "Solar Research" by Walter Semerau.

JAMES W. GAGAN
17 Bellevue Ave.
Revere 51, Mass.

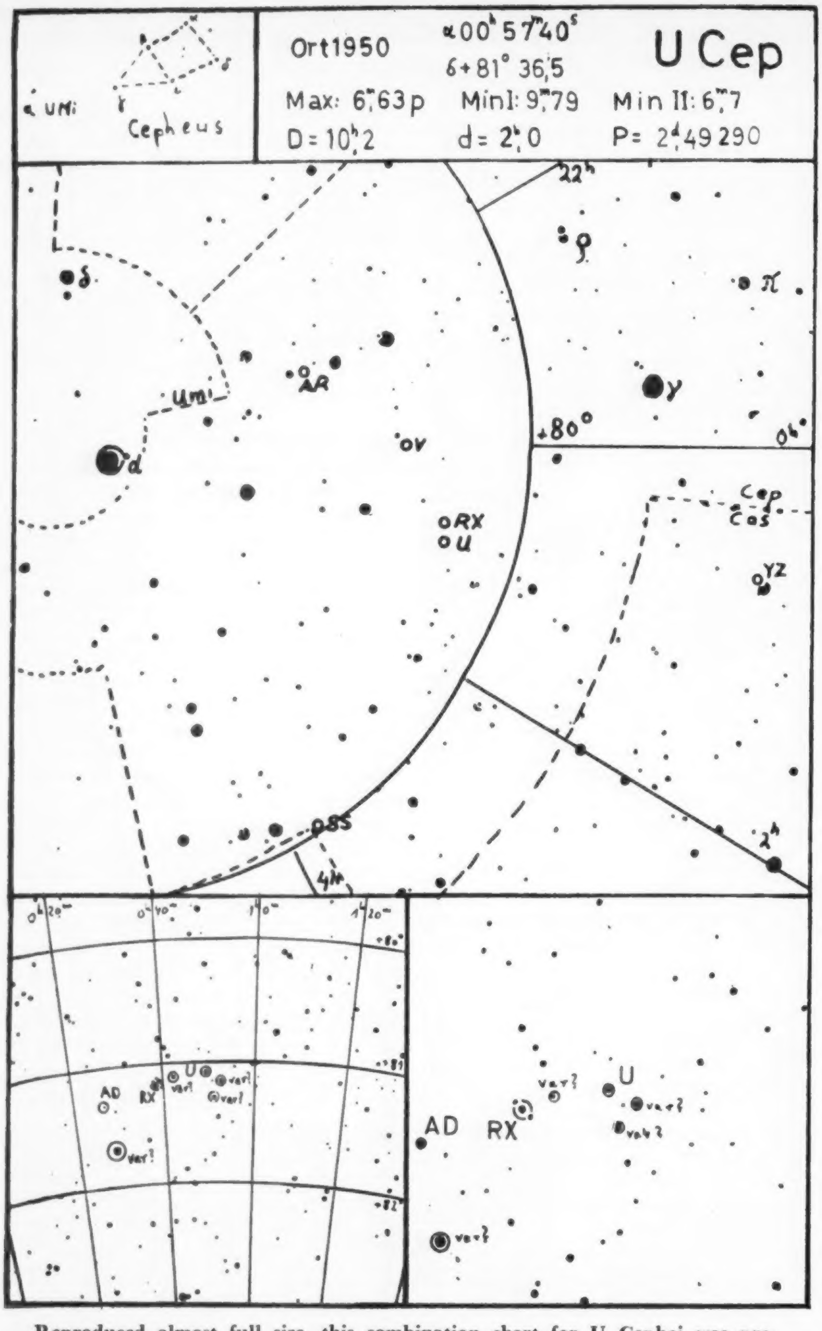
VARIABLE STAR SOCIETY IN GERMANY

In 1950 the Berliner Arbeitsgemeinschaft für Veränderliche Sterne (BAV) was founded by a group of amateur astronomers in Berlin especially interested in variable stars. The first such organization in Germany, it soon became a center for systematic observing by amateurs. We also co-operate closely with the AAVSO, sending them monthly reports.

Our headquarters are located in the public Wilhelm Foerster Observatory, where amateurs carry on all the scientific work, the institution supplying many of the necessary instruments. The most effective one for our purposes is the 12-inch Bamberg refractor.

Some 20 members of the BAV are now actively engaged in timing minima of eclipsing variables. Several times a year they receive the *BAV Rundbrief*, a circular containing about 12 pages of observations, ephemerides, and other pertinent information. We now have 75 eclipsing stars under systematic observation; these were listed in the *Rundbrief* for January, 1958.

When most of our members lived in Berlin, it was unnecessary to construct



Reproduced almost full size, this combination chart for U Cephei was prepared by the Berlin Group for Variable Star Observing. Seventy-five such diagrams, covering all stars in the society's program, will soon be available.

field charts for these stars, since the star charts and atlases at the observatory could be used. However, now that our membership has expanded, we are mapping the fields of all stars in our regular program.

A typical sheet is approximately six inches wide by 8½ inches high, and contains a constellation sketch and three progressively more detailed maps of the variable's region. Also included is information about the star's co-ordinates, magnitudes at maximum and minimum, duration of eclipse, and period. Other variables in the same field are marked, to prevent their accidental use as comparison objects. Observers interested in eclipsing binaries may buy these charts for 10 cents each.

Our organization would like to find collaborators in the United States. There is a special need for observers with large telescopes (12-inch or so) for work on the fainter eclipsing variables.

WOLFGANG QUESTER
BAV, Wilhelm Foerster Sternwarte
Papestrasse 2
Berlin-Schöneberg
West Germany

+++ Amateur Briefs +++

Much-enjoyed activities of the Clinton County Astronomy Club in Frankfort, Indiana, have been field trips to various places of astronomical interest. At 5 o'clock one early spring morning, club members climbed into the back of a panel truck, furnished with hay bales, for a trip to Chicago and the Adler Planetarium. The expedition was successful, although all the way home the truck unwittingly played tag with a tornado, at one time being only five minutes ahead of the storm's center!

Reports of observations received by the Montreal Centre of the Royal Astronomical Society of Canada are filed in a pigeonhole rack over the library desk and then picked up promptly by the respective section chairmen.

Suggesting summer uses for a telescope, the bulletin of the Amateur Astronomers Association of New York City quotes from a letter by the old-time telescope maker, John Brashear: "Of an afternoon, Dr. Samuel Langley would come over to my shop to watch the baseball games as the park was in sight and a telescopic view of the game was very satisfactory."

Dewey Schwartzenberg, Jr., 14, vice-president of the Shreveport Junior Astronomical Society, won top honors at the Louisiana State Junior Science Fair, and will represent his state at the national fair to be held in Kansas City. In his project, the Milky Way and the Messier objects he had personally observed were represented on a globe.

A 100-volume astronomical library gathered by the amateur Alvin J. Aucoin of Houston, Texas, before his death in 1940, has been donated to the local Lamar High School Astronomy Club by his wife and son. In the collection are several 19th-century works, by such writers as Grant, Smyth, Proctor, and Loomis.

One member of Rochester Moonwatch, according to the team's leader, Russell Jenkins, prepared diligently to observe satellite 1960ι1. He computed the precise time and altitude of an expected meridian transit, arranged his equipment, and then spent several minutes adapting his eyes to the darkness. At the predicted time, 1960ι1 appeared, a brilliant, unmistakable object. Much to the Moonwatcher's chagrin, he realized his elaborate preparations were for Echo I!

New quarters of the Astronomical Society of South Australia are located at the Norwood Boys' Technical High School, Adelaide. Recently, a used 12-foot observatory dome was donated to the society by Dave Rumball. Transporting the dome to the school grounds proved quite an undertaking, but with 13 good men, a large flat-bed truck, and an escorting convoy of a dozen cars, it was successfully managed. The dome is now being repaired, scrubbed, and painted, and its concrete foundation built. G. B. C.

Ten Years of Solar Eclipses

Four saros cycles before February 15, 1961, the eclipse of January 1, 1889, was observed along a path running from north of San Francisco to the Hudson Bay region. This photograph was taken by the Harvard expedition in Willows, California, with a 13-inch telescope.

DURING the decade from January, 1961, through December, 1970, the shadow of the moon falls upon the earth 22 times. These events occur as eight total, eight annular, and six partial eclipses of the sun. Every continent will see at least one of them, weather permitting.

The tables contain some information on the dates and locations of eclipses in this period. On the following pages is a map indicating the central lines of the total and annular events.

Although the number of eclipses is the same as in preceding and succeeding decades, eight of them are total during 1961-70, compared with six in 1951-60, and seven in 1971-80.

PARTIAL SOLAR ECLIPSES 1961-1970

Date	Magnitude	Where Visible
1964 Jan. 14	0.559	Antarctica, Tasmania, S. America
Jun. 10	0.754	Australia, Tasmania, New Zealand
Jul. 9	0.322	Asia, Canada, Arctic
Dec. 3-4	0.752	Hawaii, Japan, Asia, Alaska
1967 May 9	0.720	N. America, Greenland, Scandinavia
1968 Mar. 28-29	0.899	Antarctica, S. America

The magnitude of an eclipse of the sun is the fraction of the solar diameter covered by the moon at maximum phase, measured along the line connecting the centers of the disks.

Three total eclipses are of special interest because of the areas over which they pass. The first occurred last February, crossing southern Europe and part of Asia (SKY AND TELESCOPE, April, 1961). It will probably prove to be the most widely observed eclipse of the period.

On July 20, 1963, the moon's shadow will race across North America. Although much of the path will be over land, the short length of totality may hamper some types of observing programs. In Alaska, the duration will be about 1½ minutes, but totality will have dwindled to only 59 seconds by the time the shadow reaches the coast of Maine.

The somewhat longer totality associated with the eclipse of March 7, 1970, makes it more favorable. The path crosses Central America and Florida and skirts the eastern seaboard. Although totality is largely over water, the accessibility of land observing sites, combined with the high altitude of the sun (totality occurring shortly after noon in the United States), is likely to attract many professional and amateur astronomers. The maximum duration of totality is 3½ minutes, near Coatzacoalcos in southern Mexico, but it will last about three minutes in Georgia and the Carolinas.

The November 2, 1967, eclipse is unique among the 22, because the axis of the moon's shadow will not touch the earth's surface. Sweeping past the Southern Hemisphere, the edge of the umbral shadow will fall on a small area of ocean north of the Weddell Sea, but the center of the shadow cone will miss the earth by about 14 miles. Such a near miss last took place on October 23, 1957, in the same part of the Antarctic. This total eclipse will probably be observed by fewer people than any other during the decade.

Occurring in high northern latitudes, the eclipse of September 22, 1968, will follow a north-to-south path, rather than the more common west-to-east track. The eastward sweep of the shadow will be nearly matched by the turning of the earth, resulting in a central line that ends slightly west of where it started.

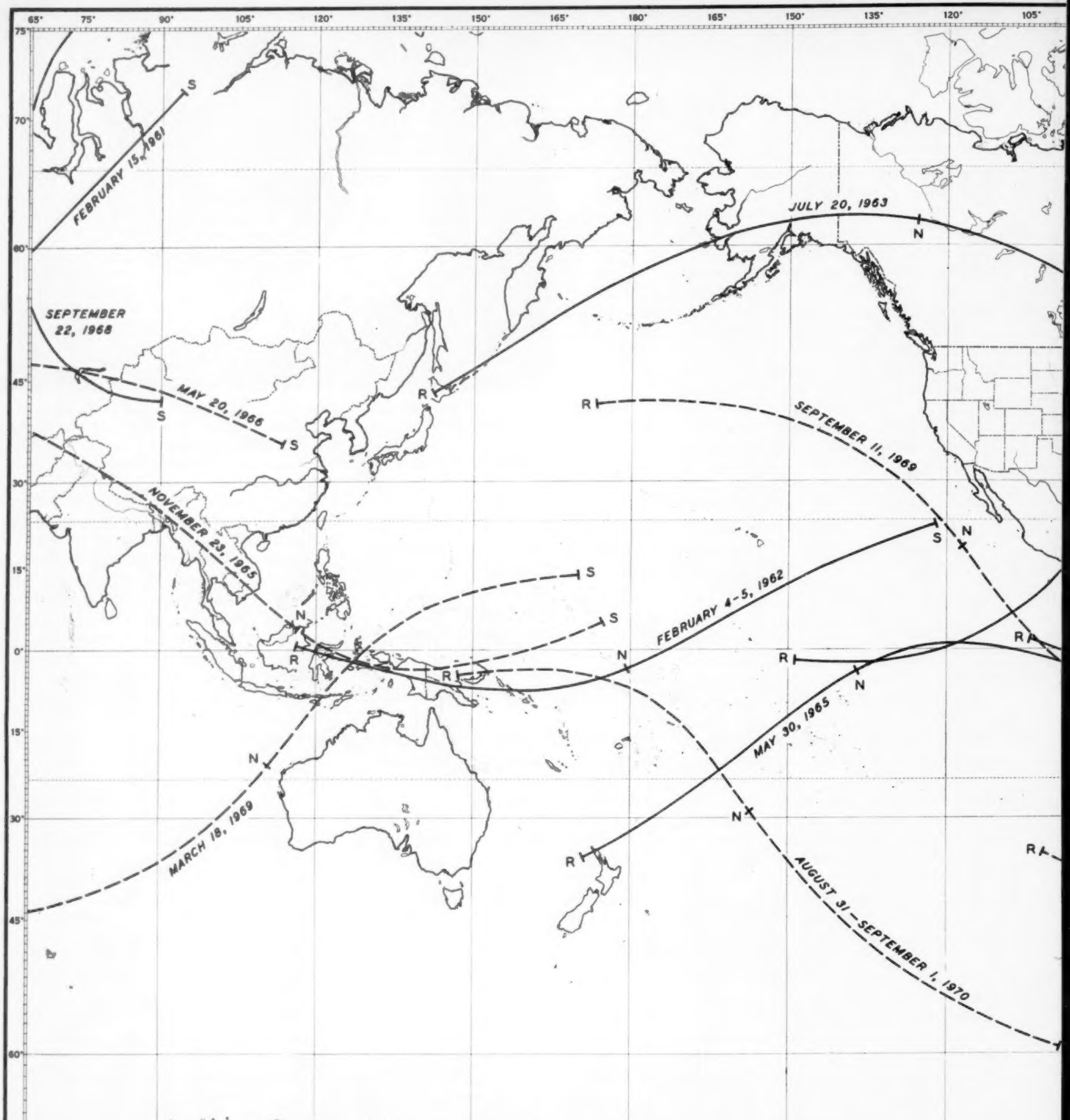
The longest duration of totality will come with the eclipse of May 30, 1965. Unfortunately for observers, the central line falls almost entirely over water. The shadow passes north of New Zealand, crosses the Pacific, and leaves the earth in Peru, not from from the coast. In mid-Pacific the sun will be hidden for a total of 5¼ minutes.

South Americans who miss the 1965 eclipse because of the shortness of its path over the continent will be solaced by another passage of the moon's shadow

TOTAL AND ANNULAR SOLAR ECLIPSES 1961-1970

Date	Type	Duration m s	Width Miles	Location
1961 Feb. 15	T	2 45	164	Europe, Asia
Aug. 11	A	6 35	323	South Atlantic
1962 Feb. 4-5	T	4 08	91	Central Pacific
Jul. 31	A	3 33	100	Atlantic, Africa
1963 Jan. 25	A	1 01	46	South Atlantic
Jul. 20	T	1 40	63	North America
1965 May 30	T	5 16	124	Pacific
Nov. 23	A	4 05	108	Southern Asia
1966 May 20	A	56	40	Africa, Asia
Nov. 12	T	1 57	52	S. America, S. Atlantic
1967 Nov. 2	T			Weddell Sea
1968 Sep. 22	T	40	68	North Central Asia
1969 Mar. 18	A	1 14	44	Indian Ocean, Pacific
Sep. 11	A	3 15	104	North Pacific
1970 Mar. 7	T	3 28	98	North America
Aug. 31-Sep. 1	A	6 48	188	South Pacific

Successive columns give the date of each eclipse, its type (total or annular), the maximum length of time between second and third contacts, the maximum width of the path from which the eclipse may be seen as total or annular, and the general area of the earth over which the path passes.



Paths of total eclipses (solid lines) and annular (dashed lines) occurring in the decade 1961 to 1970, drawn on a U. S. Hydrographic Office chart. R, N, and S indicate local sunrise, noon, and sunset, respectively.

only a year and a half later, on November 12, 1966. This time the eclipse will go slightly south of the end of the previous one and then continue across Bolivia, Argentina, and southernmost Brazil.

The only total eclipse with a central line that does not touch any continent will come on February 4-5, 1962. Because the path crosses the international date line the event will occur on both the 4th and 5th.

Two of the annular eclipses are quite lengthy. On August 11, 1961, six minutes and 35 seconds will elapse between second and third contacts. Even this is 13 seconds less than the duration predicted for the last eclipse of the decade, occurring on August 31 and September 1, 1970. But the central line of the latter falls over the Pacific and the former crosses the South Atlantic, where few people will view the spectacle of the bright solar ring around the moon.

There will be ample opportunities for

The hatched area in the Weddell Sea indicates shadow coverage for the noncentral total eclipse on November 2, 1967. A small part of the path in the Arctic of the September 22, 1968, eclipse is omitted.

such observations, however, since annular eclipses will be visible from Africa, Europe, Asia, and South America. Although not as important to astronomers as total eclipses, because the corona is not seen, annular eclipses draw much local attention and are useful in geodetic studies.

Two successive annular eclipses, July 31, 1962, and January 25, 1963, may be valuable for such purposes. Since each crosses parts of two continents, measurements may be made to determine transoceanic distances, thus tying together trigonometric surveys of the two land masses.

In all, the decade should be of interest to eclipse observers, since the paths of three total eclipses are largely over land, with three others presenting reasonably good observing possibilities. SKY AND TELESCOPE will carry more detailed information about some of the coming eclipses near the times of occurrence.

R. N. W.

OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Mutual Phenomena of Jupiter's Satellites

During the second half of this year, the orbits of Jupiter's four bright satellites will be turned nearly edgewise to the earth. Consequently, there will be a number of occultations and eclipses of one Jovian moon by another.

The accompanying list of predictions includes only the more conspicuous of these phenomena visible from the United States. It has been extracted from a full list in the 1961 *Handbook* of the British Astronomical Association.

The mutual occultations are best observed with large telescopes and high powers capable of revealing clearly the satellite disks. Careful timings of the contacts are desirable.

Smaller telescopes are well suited for following the eclipse of one satellite by the shadow cone of another. In this case, the decrease in brightness and subsequent recovery of the eclipsed moon can be observed by means of comparison with other satellites or with field stars. A particularly striking event of this class is the eclipse of **II** by **III** on September 27th, when the former will fade to near-invisibility and brighten again within a 54-minute interval. An observer wishing to derive a light curve of these rapid changes might well use a tape recorder for his brightness estimations.

1961	*Occultation of*	*Universal Time*
Aug. 29	II by III	7:04 - 7:11
Sep. 26	II by I	6:03 - 6:31
Oct. 4	II by III	1:41 - 2:09
Oct. 14	II by I	1:38 - 1:47
Nov. 7	II by I	22:36 - 22:39
Nov. 22	II by I	3:33 - 3:36

Note that the predicted durations are mostly only a few minutes, but in some instances much longer. Brief events result when one moon is on the nearer side of Jupiter, the other on the farther side, so they pass quickly in opposite directions. The very extended duration of the September 27th eclipse comes from **II**'s slow motion just after eastern elongation, which nearly matches the speed of **III** and its shadow.

1961	*Eclipse of*	*Universal Time*	*Mag.*
Aug. 22	II by III	6:17 - 6:24	0.30
Sep. 12	II by I	2:49 - 3:21	0.57
Sep. 19	II by I	6:40 - 6:54	0.64
Sep. 27	II by III	4:36 - 5:30	0.98
Oct. 7	II by I	1:42 - 1:50	0.66
Nov. 8	II by I	0:45 - 0:49	0.38
Nov. 27	I by II	1:33 - 1:36	0.33
Dec. 4	I by II	3:47 - 3:50	0.33

Mag. is the magnitude of eclipse — the fraction of the diameter of the remoter satellite that is shadow-covered at mid-eclipse. The eclipses of November 27th and December 4th are annular, the smaller satellite being in front.

SZ HERCULIS PREDICTIONS

The Algol-type variable star SZ Herculis is now conveniently placed for observation with telescopes of 6-inch aperture or larger. A finder chart and other information were given on page 508 of the June, 1960, issue. The magnitude range is 10.2 to 11.9, eclipses occurring every 0.818 days. Only 2.2 hours are taken for this variable to fade from maximum to minimum light, and an equal interval to recover full brightness.

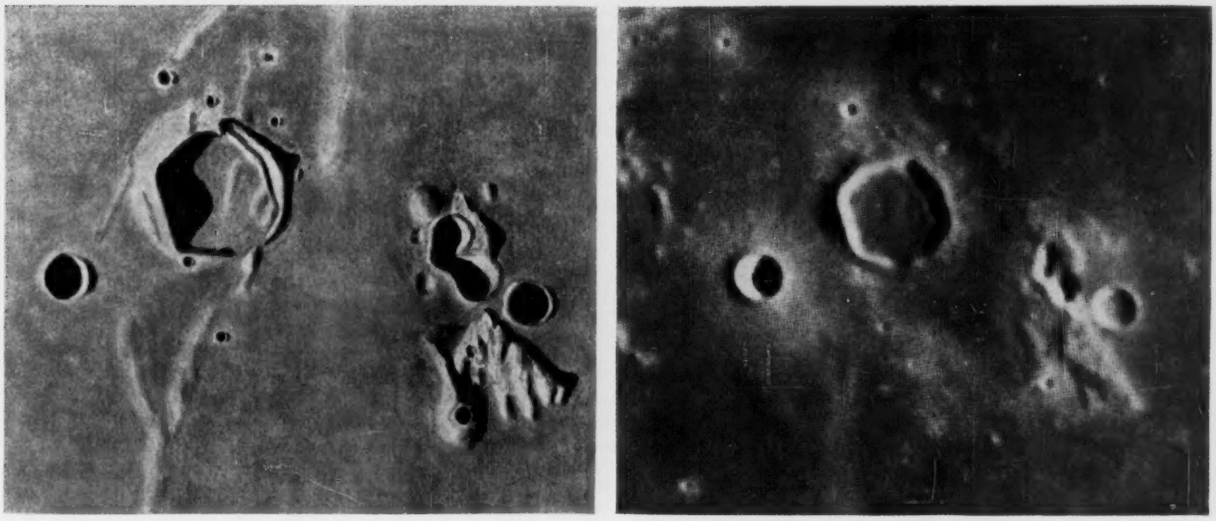
Because the period of SZ Herculis is changing, new timings of its minima are very desirable. All that is needed is a series of magnitude estimates at roughly 10-minute intervals during the hour preceding and the hour following minimum. Readers who make such observations are invited to send copies of their records to Sky and Telescope for analysis.

During the next two months, minima occurring at convenient hours for North American observers are predicted for the following Universal times, expressed in hours and tenths:

July 1, $6^h.1$; 6, 3.9; 10, 6.1; 15, 3.9; 19, 6.1; 24, 3.9; 28, 6.0.

August 2, $3^h.9$; 6, 6.0; 11, 3.8; 15, 6.0; 20, 3.8; 24, 6.0; 29, 3.8.

Other minima may be predicted by adding multiples of 19.63 hours to these times.



Left: Mr. Herring's drawing of Lassell was made with a 12½-inch reflector at 275x, on August 1, 1960, at 3:30 UT. South is above, east to the right. The dome mentioned in the text is about one inch from the picture's right edge. Right: Part of sheet D5-a of G. P. Kuiper's "Photographic Lunar Atlas," from a Mount Wilson 100-inch reflector plate.

Observing the Moon — Lassell

NEAR the western border of Mare Nubium is the small crater Lassell, east of Alpetragius and nearly midway between Davy on the north and the Straight Wall on the south. Approximately 14 miles in diameter, it lies near the center of an almost obliterated ring, one of a chain of large ancient rings that paralleled the western edge of the mare (SKY AND TELESCOPE, April, 1959, page 335).

The crater is an irregular hexagon with walls that are generally low and dilapidated. The highest portion of the rim may be about 2,300 feet, on the west, and a peak of somewhat lesser height sits on the east. The outer wall drops sharply to the level of the outside plain on the east, but the western slopes are much more gentle. Narrow gaps interrupt the walls on the north and south, with a number of small craters near these openings.

Inside Lassell there are few conspicuous details except for a group of low hills and ridges scattered about the floor. I have suspected an extremely delicate rille concentric with the west wall, a feature that other observers should look for. The inner east wall has an easily seen terrace, similar to those in numerous craters on the moon. Probably they were formed by partial collapse of the walls when support on the inside was withdrawn; it may be that subsidence has played an important part in crater formation.

The plain surrounding Lassell contains a number of low ridges, mostly oriented north and south. They appear similar to other wrinkle ridges, many of which tend to be concentric with mare borders. These small ridges require oblique lighting to be well seen. In the Lassell area are also numbers of craterlets, ranging from small pits scarcely a mile across to 6-mile Alpetragius B, prominent in the left part of the accompanying drawing.

East of Lassell is a clump of low irregular hills, one of these small peaks having a readily seen summit craterlet. Near these hills is a curious group of several coalesced craters, bounded on the east by a little hill and on the west by several saucerlike depressions. Adjoining these craters on the south is a small circular hill. With a diameter of 3.7 miles and sides inclined less than three degrees to the horizontal, this gentle swelling has an over-all height of only about 500 feet. It seems very similar to domes occurring elsewhere on the moon's surface.

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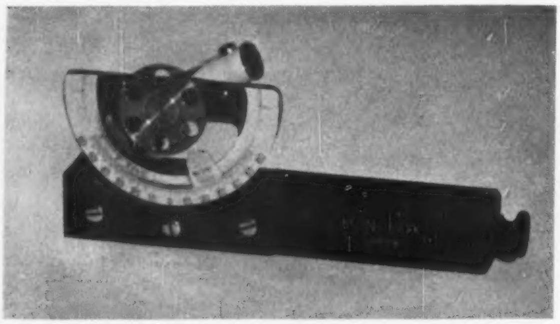
OBSERVING WITH A CLINOMETER

THE Abney-type clinometer is an inexpensive pocket-size device used by builders and engineers to determine vertical angles. It can readily be employed for measuring the sun's altitude if a very dense filter is added, and therefore I have made some tests of its suitability for approximate determinations of geographical position and local time.



A clinometer such as this can be used for a variety of simple experiments in practical astronomy. The observer sights through a small peephole in the right end of the square tube. The inclined gray tube (partly hidden) holds a spirit level which provides an artificial horizon.

The unit consists of a tube five inches long, with a viewing hole at one end and a horizontal wire at the other. A mirror arrangement brings the image of a spirit-level bubble into the same field of view, provided the altitude does not exceed 40°. In observing the sun, its disk is bisected by the horizontal wire, and a knob is turned to place the bubble alongside the wire. The vertical angle is read from an arc of one-inch radius, graduated in degrees, with the aid of a vernier indicating 10 minutes of arc. In the experiments, each observation of the sun consisted of the average of five settings taken in rapid succession.

From a comparison of 55 observed altitudes with computed values, the index correction was found to change from $-4'$ at 8° to $+3'$ at 35°. The mean error of a single observation was $\pm 5'.2$. A series of 39 observations of the sun's altitude around noon gave the geographical latitude of my observing station at Weston, Massachusetts, as $+42° \ 21'.4$ — only $0'.6$ or 0.7 mile south of the true position.

Compared with a bubble sextant, this simple hand-held nontelescopic device yields quite satisfactory accuracy, and is cheaper and much more compact. It has, however, two serious disadvantages. Altitudes greater than 40° cannot be measured, and lack of artificial illumination for the bubble restricts observations to daytime or bright twilight. Hence, for astronomical applications, only the sun, moon, and Venus are available.

J. A.

SUNSPOT NUMBERS

The following American sunspot numbers for April have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

April 1, 77; **2,** 58; **3,** 71; **4,** 75; **5,** 82; **6,** 81; **7,** 61; **8,** 51; **9,** 44; **10,** 34; **11,** 40; **12,** 41; **13,** 36; **14,** 49; **15,** 39; **16,** 58; **17,** 68; **18,** 70; **19,** 70; **20,** 60; **21,** 43; **22,** 38; **23,** 27; **24,** 43; **25,** 43; **26,** 54; **27,** 70; **28,** 85; **29,** 77; **30,** 86. Mean for April, 57.7.

Below are provisional mean relative sunspot numbers for May by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

May 1, 102; **2,** 84; **3,** 72; **4,** 55; **5,** 42; **6,** 36; **7,** 31; **8,** 28; **9,** 44; **10,** 46; **11,** 45; **12,** 56; **13,** 52; **14,** 46; **15,** 38; **16,** 31; **17,** 23; **18,** 44; **19,** 47; **20,** 59; **21,** 58; **22,** 66; **23,** 74; **24,** 78; **25,** 72; **26,** 47; **27,** 41; **28,** 38; **29,** 36; **30,** 41; **31,** 24. Mean for May, 50.2.

Sunspot activity continues to decline and now is back at the level of late 1955. Dr. Waldmeier has made the following predictions of smoothed monthly sunspot numbers for the coming months: July, 59; August, 56; September, 54; October, 52; November, 49.

DEEP-SKY WONDERS

TO MANY OBSERVERS, globular clusters are the most majestic objects in the sky. In the northern heavens they appear mostly alone – riding like solitary galleons on a vast sea. But the region of Scorpius, which is well up above the southern horizon this month, abounds in both open and globular clusters.

The picture here, from E. E. Barnard's *A Photographic Atlas of Selected Regions of the Milky Way*, gives a hint of the riches of this area. In the upper (northern) part of the photograph is Rho Ophiuchi and its surrounding nebulosity; Antares is at bottom left. To the right of Antares is the rich globular M4, while above and to the right of the star is another globular, NGC 6144, forming a squat triangle with Antares and M4. A third globular is M80, near the right edge of the upper part of the picture.

M4 (NGC 6121) is a good object for beginning a tour of this field. Easily found by working from Antares, it is at right ascension $16^h\ 20^m.6$, declination $-26°\ 24'$ (1950 co-ordinates). Helen S. Hogg lists only six other globulars having diameters greater than its $22'.8$ (about two-thirds the apparent size of the moon!). But of these six, only M13 is in the northern sky, the others being far to the south.

Mrs. Hogg lists M4's photographic total magnitude as 7.41, and others have recorded visual magnitudes as bright as 6.8. I have seen this object easily with the unaided eye from Kansas, Colorado, and Arizona, and would estimate it as 6.5. In northerly England, T. W. Webb could see it only as "large and dim." But for even small telescopes in the United States it is a splendid subject; in southern latitudes it rivals M13.

The fairly conspicuous NGC 6144 is absent from Norton's *Star Atlas*, although it is only slightly fainter and smaller than M72, the faintest globular in Messier's list. With a magnitude of about 10 and a diameter of $6'$, it is quite easy. Look for it at $16^h\ 24^m.2$, $-25°\ 56'$.

M80 (NGC 6093), at $16^h\ 14^m.1$, $-22°\ 52'$, is $5'$ in diameter and said to be of the 8th magnitude, though it appears brighter to me. One meets it easily in sweeping, and it seems to have a concentrated central glow that stands out. It was in M80 that nova T Scorpii blazed in 1860, the only known case of a nova associated with a globular cluster.

There are too many globulars to the east and south of this region to list here, but the sky watcher enjoying an exceptionally clear night should try for NGC 6541, down near the end of the Scorpion's tail. For observers at latitude 40° north, this cluster can climb only about 6° above the horizon. Located at $18^h\ 04^m.4$, $-43°\ 44'$, it will be a severe test. Yet this globular has nearly the same diameter and magnitude as M13. I would appreciate a card from anyone who can obtain a clear view of this unfamiliar object.

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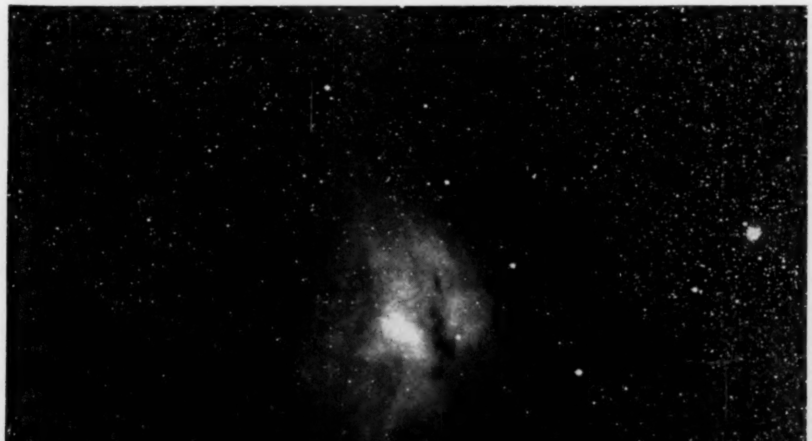


This photograph of the vicinity of Rho Ophiuchi and Antares was made in 1905 by E. E. Barnard using a 10-inch lens of 50-inch focus, the exposure being 4½ hours. The nebulosities cannot be seen visually. Reproduced courtesy of the Carnegie Institution of Washington.

THE MOONS OF JUPITER

Once, not too long ago, there was a king with but two interests in life: astronomy and his three daughters, whom he named after the moons of Jupiter — I, II, and IV. His son III he had banished years before for using one of the royal telescopes as a burning glass to light firecrackers.

Time passed, and the king grew old and almost blind. His study of the sun and stars gave him a perpetual squint, and earned from his subjects the fond nickname of King Leer. Realizing that his observing days were nearly over, he decided to bequeath to his daughters his two most prized possessions — refractors of most marvelous and rare quality (not quite UNITRONS, but still the best in all the land).

"Now have I but two refractors and three daughters," he thought to himself, "and I myself shall want to observe from time to time, when the fog of the years lifts momentarily from my eyes. I know what I shall do; I shall leave the telescopes to the two daughters who love me most. They will let me observe when I like."

And so he called his daughters before him. "How much dost thou love me, dearest I?" he asked. "My love burns brighter than a thousand suns," answered I, whose heart was in reality harder than the bearings in a UNITRON mounting.

"Thou dost please me much," King Leer said. "And now II, how much dost thou love thy father?" "My love," said II with a shrewd glance at I, "burns brighter than a thousand suns seen through a thousand UNITRONS," and the king did not know her heart was harder even than the glass in UNITRON optics.

"Dost thou love me more than this?" asked the king of IV, his favorite. "What has thou to say?" "Nothing," said IV.

"Come, come," said King Leer, "nothing will come of nothing."

"My love is richer than my tongue," replied IV; and this was true, for her heart was as docile as the slow-motion controls of a UNITRON.

The king was enraged, and on the spot he gave his two telescopes (the best in the land, though not up to UNITRON's standard) to his two deceptive daughters, and to IV he left only $12.50 plus a small pittance every month, along with an outdated Julian Day Calendar, which UNITRON prints annually for the AAVSO. IV, dejected, left his royal sight.

Next night he went to visit his daughter I, planning to study the star clusters in Scorpius.

"Go away!" she snapped. "I am searching for Venus' moon, and I want no doddering old fool at my eyepiece!"

The king, thunderstruck, left I, without even pointing out that Venus' moon had not been seen since 1764. "I will go to II," he said, brightening. "She will surely let me use her telescope."

But a servant met him at II's door, and said that his mistress was too busy trying to find the missing Messier objects to be bothered with him. The king tried to force entrance to his beloved daughter, but was brought up short by her trained mastiffs. "The little dogs and all," he said, "Tray, Blanche, and Sweetheart, see, they bark at me."

Filled with remorse and repentance, he searched far and wide for IV, realizing now that she alone really loved him. One day, while admiring from afar the observatory atop a 17-story town house, he was astonished to see IV appear at the door. "How came you here?" he cried as he rushed into her arms.

"It was all your priceless gift. But for the Julian Day Calendar, I would never have heard of UNITRON. But for hearing of UNITRON, I would never have sent for their free Observer's Guide and Catalog. But for the Catalog, I would never have found out about their Easy Payment Plan. I put down the $12.50 you left me and agreed to pay the small pittance every month. In return UNITRON sent their wonderful 2.4" Altazimuth Refractor, and that was how I met Harry."

"I don't understand," said the king.

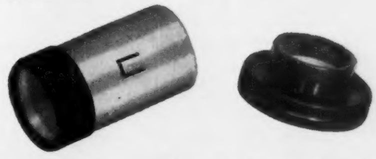
"I was observing the star clusters in Scorpius one night with my new UNITRON," she replied. "Harry happened to come by and asked if he could look too. I said it was difficult for two to look through one eyepiece. 'Not with a DUETRON!' he said, and bought me one. We found observing with the DUETRON so pleasant that one day he asked me to become his satellite. He loves astronomy."

"And is that immense observatory on the roof for your UNITRON 2.4" refractor?" asked the king, somewhat puzzled.

"Well, no," replied IV. "It seems that Harry already had a UNITRON 6" Photo-Equatorial with clock drive. We put the DUETRON on that, and we've been happily UNITRONing ever since. Would you care to join us? You can have my 2.4" UNITRON."

The king was delighted, and immediately rushed to the roof to try his new possession. "What magnificent definition!" he cried as he gazed with wonder into the eyepiece. It turned out that he was not going blind after all; the prized refractors he had given his daughters simply did not show the heavens as clearly as a UNITRON.

ANOTHER NEW UNITRON EXTRA:



In this case, UNITRON's brand new Achromatic Amplifier — a two-element, color-corrected Barlow-type negative amplifying lens designed especially for UNITRON Refractors.

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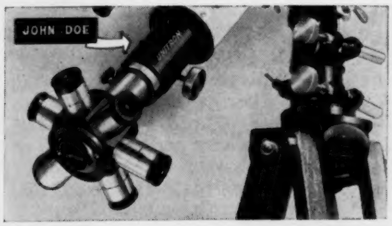

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BOOKS AND THE SKY

PLANETS, STARS, AND GALAXIES

Stuart J. Inglis. John Wiley and Sons, Inc., New York, 1961. 474 pages. $6.50.

According to the jacket, this handsome book is written for nonspecialist readers who "like to speculate for themselves about the universe." That is, the author sets out to acquaint the reader with the major, unsolved problems of astronomy — the frontiers of the subject — without requiring of him any specialized preparation in mathematics or physics.

It is often argued that this is an impossible task. "The frontiers of a science are so far removed from the layman's level of discourse," say the specialists, "that many years of technical preparation are necessary just to comprehend the problems." Such a defeatist attitude is responsible, no doubt, for the ever-expanding undergraduate requirements for science majors, and for the gulf between science and art so eloquently described by C. P. Snow. Surely there is an urgent need in our society to provide good literature that informs the public of just what scientists are doing.

Mr. Inglis is to be commended for the goal he set for himself. He is well qualified, as a college instructor in astronomy and a planetarium lecturer, to undertake the task, and has drawn wisely on the considerable resources of West Coast observatories for illustrations and for the most recent professional thinking in research astronomy.

To some extent, *Planets, Stars, and Galaxies* achieves its goal. The illustrations are of good quality, the diagrams are clear, and there are but half a dozen simple equations in the whole book. The reader needs only an understanding of graphs, ratios, and powers of 10.

The text is clear enough, with few unexplained terms and symbols, but is arranged somewhat too strictly in textbook style, without notable inspiration or elegance. The author uses a strongly deductive approach, proceeding "logically from paragraph to paragraph and from chapter to chapter, so that the discussion of each new topic represents a coherent development of the preceding material," as the statement on the jacket so aptly puts it. Many teachers of elementary astronomy will welcome this coherence, but it immediately structures the subject in a form to be learned rather than enjoyed. In this regard the book is no better than several other recent introductory texts, although it does cover more of the interesting problems of modern astronomy.

What is really needed for the nonspecialist reader, and what Mr. Inglis has not provided, is a contribution to the literature of science, a book that reveals the connected nature of the subject without being pedantic, a book that draws on the excitement of exploration and discovery from cover to cover, and emphasizes the *process* of scientific inquiry as well as the results.

After a brief historical introduction, Chapter 2 turns quite logically to basic tools and methods of astronomy, from optical telescopes and Schmidt cameras to spectrographs, photometers, and radio telescopes. Then, in a mere 11 pages, Chapter 3 treats the atom, atomic structure, energy levels and series in the hydrogen spectrum, and nuclear reactions — the proton-proton reaction and (oddly) the last step only of the Bethe carbon cycle. Chapter 4 is a routine description of the physical characteristics of the planets, and is followed by "The Planetary Motions," which starts with Ptolemaic theory and gives a page each to Copernicus, Galileo, and Kepler (without much chance of showing the reader the radical change in astronomical concepts along this historical sequence). This section ends with a summary of the earth's motions (rotation, revolution, solar motion, galactic rotation, and so forth), thus making a start on the basic question of absolute motion treated in the last chapter.

Under the title "Satellites, Natural and Man Made," the next chapter discusses the moon in considerable detail (including R. Baldwin's analysis of crater sizes and N. A. Kozyrev's spectrum of gases in the crater Alphonsus), eclipses, tides, and the known satellites of other planets. The general treatment of artificial earth satellites does not refer to specific launchings, but explains stable orbits and "weightlessness" well, and describes the Van Allen belts as an example of what new data can be obtained.

The foregoing suffices to show the general scheme followed in the remaining 10 chapters, on asteroids, meteors and comets, the sun, stellar spectra, "deviant stars" (variables and novae), multiple stars (binaries and clusters), interstellar material, and galaxies, including the Milky Way.

The publisher's promise of encouraging "intelligent speculative thinking" is limited primarily to three chapters: "The Age and Origin of the Solar System," "The Evolution of Stars," and "The Universe and Relativity." In the first of these, the theories of Buffon, Kant, Laplace, von Weizsäcker, Kuiper, and Hoyle are discussed, together with the solar system features to be explained, and the author partly succeeds in showing how a sequence of theories may slowly approach some ultimate truth, stimulating a great deal of useful research along the way.

The chapter on stellar evolution, one of the best written, starts with modern stellar models and brings in most of the supporting evidence (cluster H-R diagrams, Beta Canis Majoris stars, T Tauri stars, Herbig-Haro objects, and white dwarfs), indicating the wide variety of

observational data to be integrated into one satisfactory theory.

The last chapter, on the universe and relativity, begins with the distribution of galaxies (C. D. Shane's counts); conventionally reviews distance criteria and Hubble's law; discusses the Michelson-Morley experiment, special relativity, the geometry of curved space, the rival theories of cosmology and nucleogenesis of G. Gamow and F. Hoyle; and ends with the question of life elsewhere in the universe. I doubt that this chapter will start much speculation, intelligent or otherwise; the author has pulled so many theoretical rabbits out of his hat up to this point that the reader wouldn't dare question the magic – he simply waits for more. It is never made clear what the ground rules of cosmological speculation are; the emphasis is entirely on explication of conclusions now considered "right" or, in daring moments, "possibly right."

The value of *Planets, Stars, and Galaxies* is considerably enhanced by a glossary of new terms, a list of further readings, many of them articles in SKY AND TELESCOPE and *Scientific American* as late as mid-1959, and four or five questions or exercises for each chapter. It also has a good 11-page index, star charts, and (on the inside of the dust jacket) a photographic map of the moon.

THORNTON PAGE
Wesleyan University

CAPTURED STARS

Heinz Letsch. Gustav Fischer Verlag, Villengang 2, Jena, East Germany, 1959. 183 pages. DM 16.00.

THIS impressively titled book presents a limited, subjective analysis of the early-model Zeiss planetarium instrument now being manufactured in East Germany. It is a translation by Harry Spitzbardt of the German work *Das Zeiss Planetarium.*

Copyrighted in 1959 by Carl Zeiss, Jena, *Captured Stars* impresses this reader as being a lesser imitation of a more comprehensive, complete book about the same subject, *From the Aratus Globe to the Zeiss Planetarium.* The latter was written by Helmut Werner in close collaboration with the inventor of the Zeiss instrument, the late Walther Bauersfeld. It was copyrighted in 1953, then revised and enlarged in 1957 by Carl Zeiss, Oberkochen, West Germany.

Whether by oversight or intent, *Captured Stars* is limited because it does not contain, among other important elements, a description of the newest and improved Zeiss planetarium, installed in London about two years before the book was printed. Another of these modernized instruments has since been set up at the American Museum-Hayden Planetarium in New York, and its integral-component innovations adapted to two of the other five Zeiss projectors in this country (Chapel Hill and Chicago) and to several planetariums abroad. To be objective and complete, any authoritative text on the planetarium printed after 1957 should contain a description of these advanced features, which significantly increase the scientific utility of the instrument and reproduce the beauty of the night sky far more realistically.

Captured Stars is offered as a "considerably condensed text." This is certainly accurate, because some of the important aspects of the planetarium story have been condensed away entirely. The stated purpose of the book is to "arouse an appreciation of the ingenuity of the invention and the cultural achievement of the Planetarium." But so compressed is the text that the name and the work of the ingenious inventor have been omitted completely. Also omitted are descriptions of the diverse cultural potentials of planetariums.

The text reads as if Mr. Letsch had accepted the assignment to analyze scientifically the effects produced by the planetarium, to study available references, and to compile a book on the subject, without having personally experienced the intricacies of the physical operations.

The translation from the German is perhaps too literal, because in many instances the text requires even the initiated person to pause and ponder the accurate but uncommon phrase and sentence structure.

Although the table of contents indicates

completeness of coverage, the author has ignored the human-interest features of the planetarium. Therefore he fails to satisfy the general reader who is awed, instructed, entertained, and inspired by what the instrument can do, but seeks only a superficial understanding of the mechanical operation of this complex scientific tool. On the other hand, Mr. Letsch has not produced a book adequate for the technician who needs to understand the functional aspects of the mechanism, nor for the professional who wants a complete, authoritative reference work.

Although *Captured Stars,* with 62 pages of illustrations and 86 of text, is an impressive book, it does not accomplish its stated purpose as effectively as its competitor, *From the Aratus Globe to the Zeiss Planetarium.*

A. F. JENZANO
Morehead Planetarium

RADIO ASTRONOMY

F. Graham Smith. Penguin Books, Baltimore, 1960. 265 pages. $1.65, paper bound.

USE of the radio region of the spectrum to complement and extend man's knowledge of galaxies, stars, and the interstellar medium is only about three decades old. It is still a mushrooming field, producing several important discoveries each year. F. Graham Smith, a member of the radio astronomy group at the University of Cambridge, has made a number of important contributions to the subject, especially in determining the positions and flux densities of radio sources and in connection with the solar corona, the earth's ionosphere, and galactic radiation.

In *Radio Astronomy* Dr. Smith attempts to cover in approximately 250 pages every aspect of this very broad subject. He gives the reader an insight into the direction that radio astronomy is taking as well as where it has been. When one considers the breadth of coverage, the length of the book, and the intended audience, the author has done a good job. Any intelligent layman who enjoys reading about astronomy at the SKY AND TELESCOPE or *Scientific American* summary-article level should enjoy this treatment.

It is impossible to write a book on radio astronomy that will be completely up to date at the time of publication, but Dr. Smith comes admirably near this goal. He treats such timely topics as the zodiacal light and the boundary between the earth's upper atmosphere and the outer solar corona, whistlers, Faraday rotation, and radar astronomy. The "belt" or "spur" of continuous radiation that appears in the galactic plane just to the east of the galactic center and extends to high latitudes (a phenomenon that has still not been fully explained), the recent emphasis on measuring angular diameters of radio sources, and the novel technique of aperture synthesis are discussed.

At one point the author speculates on the level of extragalactic radio astronomy knowledge attained by a hypothetical observer on a planet somewhere inside Cygnus A, and on the limits which the noise level of his environment would place on sensitive radio reception.

It is rather unfortunate that the term "radio star" has been used throughout more than half the book; only on page 156 does the author introduce the name "radio nebula." There are a number of misprints and typographical errors, which include reference to the 250-*inch,* instead of the 250-foot, Jodrell Bank steerable radio telescope (page 115). On page 141, the author names Michigan State University as constructing a single reflector with a collecting area of five acres, for work around 70 centimeters. Michigan State is not so engaged. Perhaps the author means Ohio State or the University of Illinois, but the description does not exactly fit either institution. The amount of atmospheric refraction not only depends "on the air pressure, at ground level, and on the altitude of the star being observed," (page 207) but is also temperature dependent.

From statements made on pages 16 and 178, the reader could easily get the wrong impression that the Fraunhofer lines are formed mainly in the solar corona.

It should be mentioned that the centimeter-wave observations of Saturn and the Helix and Dumbbell nebulae, reviewed on page 182, have not stood the test of time. The diameter of each of the California Institute of Technology paraboloids mentioned on page 252 is 90 feet, not 80.

These few criticisms are minor, however, and F. Graham Smith is to be congratulated for his stimulating treatment of an exciting new field of science.

WILLIAM E. HOWARD
University of Michigan Observatory

RIVAL THEORIES OF COSMOLOGY

H. Bondi, W. B. Bonnor, R. A. Lyttleton, and **G. J. Whitrow.** Oxford University Press, New York, 1960. 64 pages. $2.25.

THIS little book grew out of a series of lectures given for the British Broadcasting Corp. by William Bonnor, Hermann Bondi, and R. A. Lyttleton, followed later by a discussion among the three of them, moderated by G. J. Whitrow. The rivalry referred to in the title is between the conventional cosmology based on general relativity, supported by Bonnor, and the steady-state theory, adhered to by Bondi and Lyttleton. The publisher recommends the book to readers who have no previous specialized knowledge, but some acquaintance with the basic notions of cosmology is highly desirable, even though no mathematics is needed.

Actually the text is a debate between Bonnor and Bondi. Whitrow acts as an

impartial moderator, while Lyttleton's contribution is limited to a bizarre piece of speculation about the charges of protons and electrons. The first two men argue about cosmology, but their real disagreement goes much deeper. They represent fundamentally different approaches to scientific theory.

Both men agree on two basic points. First, the primary test of a theory is that it agree with the observed facts. Second, in the absence of clear-cut observational tests, preference is to be given to the simplest theory that fits the available data. The more artificial assumptions a theory has to call upon, the less valuable it is as an explanation. To decide whether an assumption is natural or artificial is not so easy, however, and here Bonnor and Bondi differ strongly.

The problem is that the laws of physics and astronomy are based on observations confined to much smaller distances and shorter time intervals than those involved in cosmology: how then are we to carry these laws over to larger distances and longer times? Bonnor argues that in the absence of information to the contrary, the simplest course is to assume that the conventional laws can be carried over without modification. Since our most general theory of mechanics is general relativity, it is the latter's equations that should be used to investigate the expanding universe.

Bondi, on the other hand, believes that a cosmologist should begin by considering possible models of the universe, and then eliminate those that conflict with observations. From this point of view he believes the simplest possible theory to be that of the steady state, in which the over-all picture of the universe does not change with time. To avoid having expansion thin out the universe, he has to introduce the hypothesis of continuous creation of matter. Bondi considers this hypothesis just as plausible as any other, since it has never been disproved by observation. Bonnor, however, regards continuous creation as a completely artificial hypothesis designed merely to avoid a changing density in the universe.

The cosmological argument will eventually be settled by observation, but the philosophical argument will not. The advance of science is based on a mixture of the points of view represented by Bonnor and Bondi. The question is really one of balance, and the answer involves individual judgment. What blend of the two approaches is likely to be most fruitful for scientific progress? If the majority of astronomers incline toward Bonnor's more conventional view of cosmology, it is because their judgment tells them that Bondi's view of scientific theory is less likely to lead to fruitful results.

IVAN R. KING
University of Illinois Observatory

HANDBUCH FÜR STERNFREUNDE

Günter Dietmar Roth, editor. Springer-Verlag, Heidelberger Platz 3, Berlin-Wilmersdorf, West Germany, 1960. 360 pages. DM 48.

MANY suitable English-language books exist for the beginning amateur astronomer who wants to make a first acquaintance with the showpieces of the skies. But there are very few for the advanced amateur who needs a systematic manual describing observing methods and explaining problems he can fruitfully attack.

Probably the best volume of this kind was Joseph Plassmann's German classic of 1922, *Hevelius: Handbook for Friends of Astronomy and Geophysics.* Although now out of date in places, it is a mine of useful techniques and ideas, still well worth reading. However, copies are hard to find.

A new German book, shorter but in much the same spirit as the old *Hevelius,* is Günter Roth's *Handbook for Amateur Astronomers.* The 13 chapters were written by both professional and nonprofessional astronomers. Throughout, free use is made of elementary mathematics, allowing a much wider range of topics than would a purely descriptive approach.

The first section of some 120 pages is devoted to such matters as instruments and photography, time and astronomical co-ordinates. The coverage is similar in many ways to J. B. Sidgwick's *Amateur Astronomer's Handbook* (1955). However, the English book gives many more practical hints on construction and use of telescopes and accessories, while the more systematic German treatment provides a better insight into principles. It also touches on radio telescopes, omitted by Sidgwick.

Practical observing methods occupy nearly 200 pages. R. Müller has contributed an excellent section on solar work, as has W. Petri on solar eclipses. Worthy of special note are the three chapters on the moon, lunar eclipses, and occultations, which are much superior to the treatment of the same subjects in Sidgwick's *Observational Astronomy for Amateurs.* The planets are dealt with rather briefly, but in excellent perspective. A serious omission is of instructions for observing central-meridian transits of Jovian features and the determination of their rotational periods; this information is provided in detail by Sidgwick. Another noteworthy chapter deals with artificial satellites, but the account of visual meteor work is far less helpful than Sidgwick's.

One strong point of Roth's book is its treatment of variable star observing. Here the Argelander step technique is well explained. The difference in brightness between the variable and each of several comparison stars is estimated in terms of a small arbitrary but constant unit, the step, and a scale of step values can be constructed for the comparison-star sequence. Hence it is possible to determine the light curve of a variable and evaluate times of maximum or minimum, without knowing the magnitudes of any reference stars. Unfortunately the Argelander method is far too little known by American amateurs, although it makes possible much fascinating work outside the routine of organized variable star observing.

Roth's *Handbook* gives a revealing view of the different development of amateur astronomy in Europe and America. For the American with a reading knowledge of German, this volume will prove a fruitful source of new ideas and new techniques. Its value is enhanced by numerous illustrations, extensive bibliographies, and a well-chosen appendix of tabular data.

J. A.

NEW BOOKS RECEIVED

ARTIFICIAL SATELLITES, *Michael W. Ovenden*, 1960, *Penguin*. 128 pages. $1.25, paper bound.

A British astronomer views the past, present, and future of rocketry and space exploration. Numerous diagrams and photographs illustrate the popularly written text.

THE PHYSICAL PRINCIPLES OF ASTRONAUTICS, *Arthur I. Berman*, 1961, *Wiley*. 350 pages. $9.25.

In textbook format, this thorough exposition of the basic principles of astronautics is for students and general readers with a background in introductory physics and calculus. Particular attention is given to the foundations of mechanics, orbit theory, and propulsion dynamics.

GALAXIES, *Harlow Shapley*, 1961, *Harvard University Press*. 186 pages. $5.00.

Written by a former director of Harvard Observatory, this is one of the early titles in the Harvard Books on Astronomy, published in 1943. It has now been revised extensively.

MAN'S VIEW OF THE UNIVERSE, *R. A. Lyttleton*, 1961, *Atlantic-Little, Brown*. 108 pages. $3.95.

Illustrated with a familiar selection of celestial photographs and diagrams, this brief summary brings the general reader an up-to-date, authoritative picture of astronomical knowledge and cosmological theories.

SURFACE OF THE MOON, *V. A. Firsoff*, 1961, *Hutchinson and Co. Ltd.*, 178 Great Portland St., London W.1, England. 128 pages. 21s.

A well-known British student of the moon discusses the lunar surface from a geological viewpoint, with special reference to the tectonic grid system. The bibliography has 102 entries.

THE IMPACT OF THE NEW PHYSICS, *Frank Hinman*, 1961, *Philosophical Library*. 174 pages. $4.50.

A California School of Medicine biologist, using atomic physics, cosmology, and geology, theorizes on the origin of life.

AN ELEMENTARY SURVEY OF CELESTIAL MECHANICS, *Y. Ryabov*, 1961, *Dover*. 164 pages. $1.25, paper bound.

This account of motions in the solar system is intended for the reader who wants something more than the brief statements in popular books, but not a technical monograph. Using only simple mathematics, it should be understandable to informed amateurs. The author explains the basic ideas of gravitation, planetary orbits and their perturbations, and describes in some detail the motions of artificial satellites. This is an English translation of a Russian book first published in 1959.

TRAITÉ DE MÉCHANIQUE CÉLESTE, *F. Tisserand*, 1960, *Gauthier-Villars*, 55 Quai des Grands-Augustins, Paris 6, France. Vol. I, 474 pages, 50 NF; Vol. II, 547 pages, 60 NF; paper bound.

This is a new edition of the *Treatise on Celestial Mechanics*, which since its appearance in 1888-90 has been a classic advanced textbook on motions in the solar system. Volume I, after an introductory hundred pages on undisturbed orbital motion, deals with the problem of three bodies; the second volume is concerned with the shapes and rotations of celestial bodies. The text is in French.

EL TELESCOPIO, *Miguel Valdez*, 1960, *Miguel Valdez*, P.O. Box 1325, Antofagasta, Chile. 162 pages. $1.75, paper bound.

Directions in Spanish are given for the construction of an amateur's reflecting telescope, using this small mimeographed book.

STELLAR ATMOSPHERES, *Jesse L. Greenstein*, editor, 1960, *University of Chicago Press*. 724 pages. $17.50.

In this advanced textbook, chapters by 20 astronomers discuss in detail the interpretation of stellar spectra, with such related topics as magnetic fields and rotation of stars. While labeled Vol. VI, this is the second part to appear of the nine-volume *Stars and Stellar Systems*, edited by G. P. Kuiper and Barbara M. Middlehurst.

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FOR SALE: *Sky and Telescope*, 1952-57, except October, 1954. Best offer. L. G. Pardue, 641 Falcon, Miami Springs, Fla.

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FROM the rich legacy of designs left to amateur astronomers by Russell W. Porter, many have chosen the Springfield mounting, which combines sturdiness with the convenience of having the eyepiece in a fixed position. Usually Newtonian optics are used, introducing the disadvantage that the telescope tube must be supported at its upper end and provided with a long, awkward counterweight.

To overcome this, Porter himself suggested what he called the "beavertail" design (*Amateur Telescope Making — Book II*, page 375), employing Cassegrainian instead of Newtonian optics. The short tube can be supported near the middle, where a diagonal mirror intercepts the light beam to send it out along the declination axis. When it reaches the polar axis, the beam is reflected at a right angle to the eyepiece.

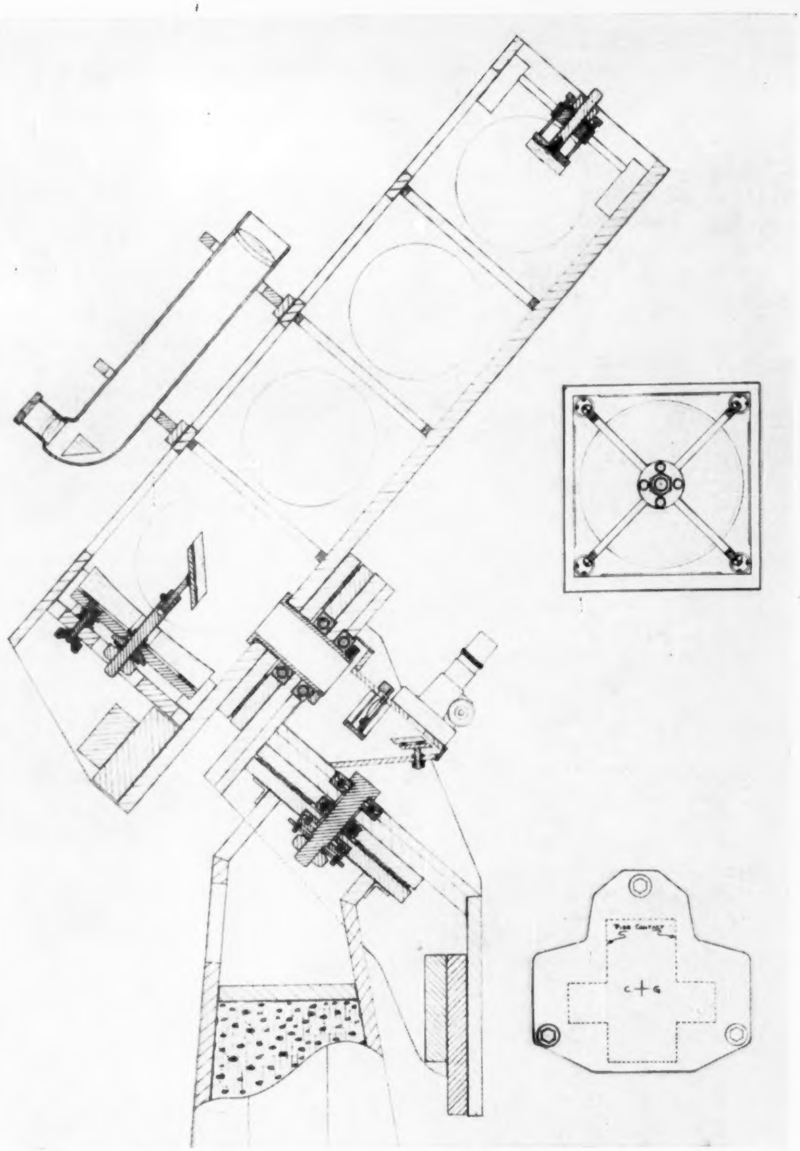
The awkward counterweight is now replaced by one hanging downward from the central mounting assembly, looking like a beaver's tail in Porter's drawing. It is filled with lead to provide the required weight.

This design impressed us as an interesting challenge for our third telescope. The advantage of observing in a comfortable position is indisputable, especially for detailed lunar and planetary work. Hence we felt that this compact instrument would permit us to do more useful observing.

We did not have large metal-working machines, nor the patience to make patterns and castings, so we decided to use the relatively new plasticized wood-particle board (Novaply, Granite Board, Timboard, and the like). It is used extensively where moisture or heat causes natural wood to warp or rot quickly, yet costs less than the best quality plywood. It is flat and uniform, much denser than natural wood, and devoid of grain. Although lacking the ultimate fastener strength of actual wood, it proved satisfactory for the tube and mounting parts.

The movable section of the mounting between the telescope tube and the pier — the heart of the Springfield design — we call the *yoke*. The hollow declination axle, which holds the tube to the yoke, has one radial and one thrust ball-bearing, as well as two silicone-greased 10"

While George Doschek observes at the main eyepiece of this Springfield reflector, his father Antony looks through the finder. The rubber-tired dolly is used to move the telescope to and from its indoor storage place. Leveling is done with the knurled knobs on the base. Photograph by Garry's.



The level of concrete in the pier of the Doschek telescope is indicated in this scale drawing. The upper inset shows the secondary mirror's spider support arrangement, the lower one the shape of the pier on its base.

16-gauge polished aluminum plates that act as friction-bearing surfaces. A thin sheet of Teflon between them would be better, but adjustment of the take-up nut against the thrust bearing now provides smooth motion of the tube in declination.

A similar friction-bearing arrangement holds the yoke onto the slanted upper surface of the pier, except that the polar-axis fastener is a solid pin with thrust bearings at each end. The cap end may be fastened to the yoke and the other driven by a clock gear and clutch inside the pier. In our manually controlled version, both polar-axis and declination bearing circles are equipped with outside ring gears turned simply by pinions, whose shafts are held in sleeve bearings through the yoke.

The controls are seen in the photographs on the right side of the yoke: a handle for movement in declination and a knob and bevel-gear reduction for right ascension. The ring gears were made from 24-pitch straight gear tracks, bent around the 10"-by-¾" circles and then fastened by long pins driven through holes drilled between the gear teeth every three inches. The small amount of backlash incurred by bending and opening up the teeth of the gear track is not detrimental in view of the frictionally damped motions of the tube and yoke.

The Springfield design requires that the axis-bearing holes be drilled accurately at right angles to the tube and yoke as well as to each other. If a slight error has been made, however, the particle board permits easy correction by sanding the friction-bearing circles. Such an error is detected as a decentering of the several

images of the optical train that are seen by looking down the polar axis without an eyepiece while the tube is rotated in declination.

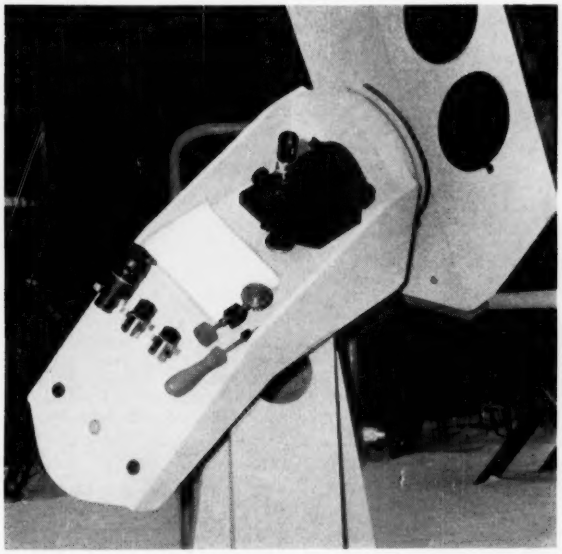
In the beavertail of the yoke we have 44 pounds of counterweight balancing the weight of the telescope tube and mirror. An easily removable aluminum cassette on the yoke (dark in the pictures) holds the eyepiece focusing rack, the inverting flat, and a slide-out holder for filters. When this cassette is removed, the focal plane falls almost at the lower edge of the "table" of the yoke, where the image may be examined or photographed.

The square tube is strong and rigid, and is readily fitted with accessories. If ground lights are annoying during observing, the round ventilation holes can be closed with thin sheet-aluminum shields. Note that the lower end of the square tube (a shape easy to construct) is cut on the bias. The part nearest the yoke carries a 26-pound counterweight that is attached to the bottom of the tube after the primary mirror is set in place.

The optics require that the secondary mirror's mounting at the upper end of the tube be extremely sturdy. The spider legs are steel rods $\frac{3}{8}''$ in diameter threaded into 1" standard pipe sleeves, which are bolted to the corners of the tube (out of the optical path). At the center, these rods hold a Micarta wafer 1" thick to carry the secondary mirror cell and the usual lateral and longitudinal screw adjustments. We wrapped the spider legs closely with coarse black wool yarn, and found that this eliminated most of the visible diffraction pattern. Presumably the diffraction now produces an imperceptible haze dispersed over the field of view.

All of the joined parts of the telescope should be cut to fit as accurately as possible. Even though wood can be "pulled" to fit, this technique should be avoided. Prefit all components by tacking them together with long finishing nails; no joint should allow a 0.002" feeler gauge to pass through. Matching joints should be rabbeted to provide greater strength.

After an assembly has been prefitted, the edges of the joints should be sized with white wood glue, or hot glue if available, and allowed to dry, after which the tears and flows should be sanded down. If clearance and pilot holes for the screws have been drilled during the prefitting, the fastenings can be tightened immediately after gluing and assembly. Use flat-head screws on 2" or 3" centers wherever possible, countersink the heads, and fill the holes with plastic wood.



The "yoke" of the telescope, showing the convenient controls for right ascension (knob) and declination (handle). The cassette holding the eyepiece and polar-axis diagonal appears dark above center. The "beavertail" extends downward to the left, holding a number of eyepieces and, at its lower end, a 44-pound counterpoise bolted on.

All holes should be made on a drill press so as to lead the screws properly. Avoid the practice of "towing" the joints, as this causes strains in the assembly. With care and proper centering, the large holes in the tube and yoke that admit the radial and thrust bearings can be bored with an ordinary swing cutter in a drill press. Clamp all parts firmly to the drill table to avoid oversized holes, as the particle board is too soft to hold the pilot drill rigidly on center.

The board's cut edges are porous, requiring a good semi-liquid sealer to be used copiously on all exposed edges after assembly. The sealer is then sanded and painted. Our telescope was given a primer of lacquer sealer, a coat of lacquer surfacer, and a final coat of Multicolor, a tough, leathery finish.

Desiring the best optics available, we asked Daniel E. McGuire, a professional optician, to make the components, the finished system having an equivalent focal length of about 185" and a focal ratio of 24. The field of view with a 26.6-mm. eyepiece is about 15 minutes of arc.

The pyrex primary, $7\frac{3}{4}''$ in diameter, is corrected to Dall-Kirkham specifications;

a $1\frac{1}{4}''$ perforation at its center is used for mounting the diagonal or coude mirror.* The primary's focal length is about $40\frac{1}{4}''$, f/5.2. The Vicor secondary mirror is $2\frac{1}{4}''$ in diameter, half an inch thick; it is convex, with a negative focal length of 13″. The axial spacing from the primary is 30.625″, the amplification factor being about 4.6.

The next two mirrors are the diagonal, 1/20-wave flat Vicor, with a $2\frac{1}{4}''$ minor axis, placed 27″ from the secondary, and the inverting mirror on the polar axis, which is of $\frac{1}{8}$-wave pyrex, minor axis $1\frac{1}{4}''$. It is located 13″ from the coude diagonal, and the final focal plane is about 5″ upward along the polar axis. The total length of the optical path is thus only about 76″.

It is difficult to describe the beauty and perfection of lunar and planetary details in this telescope. On nights when the seeing is excellent, the crepe ring of Saturn is perceptible at a glance. The red spot on Jupiter is distinctly defined. Because of the long focal ratio, eyepieces show little chromatic aberration, and no color at all is seen on the terminator of the crescent Venus, with only a bare suggestion of color on the planet's edge at magnifications over 300x. Mars shows much detail, and many subtle markings on the moon can be studied.

Needless to say, Messier objects and the like are dimmed by the long focus, but the instrument's stability permits its adaptation to a Newtonian attachment. The central field will be good at f/5.2. In fact, the telescope is so stable and well-damped that twice we have followed the Echo I satellite at 176x by manually guiding the tube at the finder scope while the other observer watched through the Springfield system.

Since September, 1959, our wooden "beavertail," which weighs over 300 pounds, has been hauled from its garage home over rough driveway and lawn the year round; its optical surfaces have been cleansed with soap suds and distilled water twice, yet there has been no observable change in the critical alignment originally made on stars.

ANTONY and GEORGE DOSCHEK
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Pittsburgh 5, Pa.

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*This method of mounting the flat coude mirror through a small hole in the primary has often been recommended by me. It is useful for those who are considering making compound reflectors with unperforated primaries. The hole is small, and centering is not so critical as with a large Cassegrainian perforation. This system gives a very stable diagonal, eliminates a second set of spider vanes, and permits reduction of what otherwise might be too great an effective focal length. It is important, of course, that before fine grinding begins the hole be drilled from the back of the mirror to within ⅛″ of the surface, then cut through from the front after figuring is completed.

R. E. C.

Checking Concentricity of Maksutov Correcting Lenses

NUMEROUS jigs have been constructed by amateurs to test for wedge in a Maksutov telescope's correcting lens. However, Warren I. Fillmore, in *Construction of a Maksutov Telescope*, page 9, mentions that only a micrometer and a good eye are needed. I have checked the accuracy of this method and recommend it to the amateur.

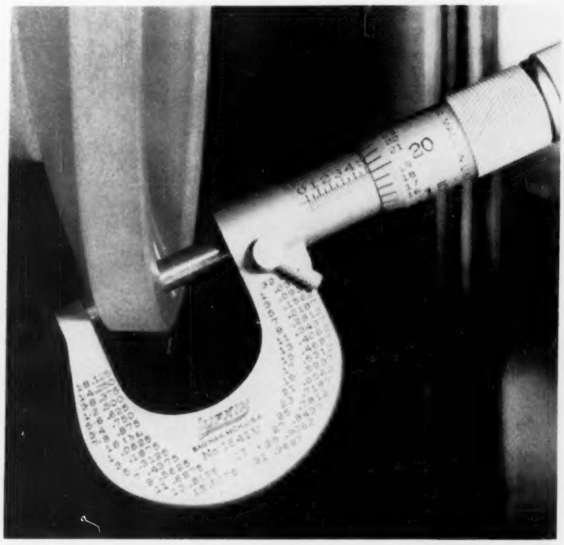
Molded blanks must be surfaced before this test can be used. After rough grinding of both sides, a flat lip is put on the front surface, reducing the effective size of the lens. Since the diameter of the blank is usually 6.4″ to 6.8″, the aperture should be brought down to the design figure of 6″. The lip gives a firm mounting surface and avoids having a sharp edge that is liable to chip or flake at the slightest impact. Figuring increases the aperture slightly, but after polishing the lip can be reground to the correct size, which will also remove any turned-down edge.

For accuracy in measuring the wedge, the lip must be of the same width all around the blank. An excellent gauge for this is a vernier caliper reading to 0.001″, used with a high-power magnifier.

The wedge-checking procedure, though simple, is necessary even for professionally prepared correctors generated on a diamond-wheel surfacing machine. The spindle of a 1″ micrometer is brought just tangent to the circle formed by the concave surface and the flat lip. To avoid damaging the lens be sure to open the micrometer sufficiently to permit it to be placed over the edge. Turn the spindle gently until it makes contact with the front concave surface while the anvil of the micrometer touches the back curve. Contrary to Mr. Fillmore's experience, I found that setting the micrometer tangent to the edge of the glass is very important when readings are taken with the vernier to the nearest 0.0001″.

To be sure that the spindle makes full contact all around its edge with the glass surface, rock the anvil against the convex side slowly and gently toward and away from the center of the lens and in a plane at right angles to this line.

During the checking procedure, I made each micrometer reading first by estimating tenths of a regular division on the spindle, and it was possible to hold the accuracy within 0.0002″ without using the vernier. This means that a careful amateur can test with an ordinary 0.001″ micrometer and still hold the wedge well under the 0.001″ given in the design figures as the maximum permitted deviation from uniformity.



This photograph by Robert E. Cox shows how to place a one-inch micrometer to check the correcting lens of an f/15 Maksutov telescope for wedge effect. At this stage, 0.021 inch had yet to be removed from the thickness to complete the grinding of the lens. Placing the spindle at the very edge of the curve gives a consistent reference position.

However, makers of Maksutov telescopes have found, in general, that if possible the error should be reduced to 0.0001″ or less for surfaces over 4″ in diameter. Checks of the blank during surfacing the concave side of the corrector shown in the picture indicated a wedge under 0.002″ at all times, so final correction was left for the convex side. After being worked until no wedge could be detected with the vernier micrometer (reading to 0.0001″), the lens was checked on a professional jig, using a 0.0001″ dial indicator. No error greater than 0.00013″ could be found, showing that a micrometer can be used without elaborate jigs, even for the most discriminating amateur optical worker.

In the last stages of fine grinding, precautions should be taken to prevent the end of the spindle or the anvil from marking the lens surfaces. The metal, since it is especially hardened, can easily scratch the glass.

ROBERT E. COX
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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

An Early-Morning Occultation of Aldebaran

MORNING TWILIGHT will be brightening the sky on July 9th as the waning crescent moon occults Alpha Tauri for watchers in the southeastern and south-central United States. The 1st-magnitude star will disappear at the bright edge of the 26-day-old moon, an event that occurs after sunrise in New England and before moonrise in Texas, where predictions are given only for emersion from the moon's dark limb.

At Washington, D. C. (Station **C**), conditions will permit watching the occultation's beginning. Disappearance there is predicted for 5:33.1 Eastern daylight time, at position angle 27° (measured eastward from the moon's north point). Reappearance at 6:18.1, 299°, will be a difficult telescopic observation requiring excellent sky conditions, as the sun will have risen half an hour before this, at 5:49 EDT.

But with sunup generally later at places west and south of Washington, the occultation circumstances become more favorable. The moon should be watched as soon as it rises that morning. The gap between it and the star will continually close, and Aldebaran should be visible with telescopic aid right up to the moment of contact with the moon's limb. Reappearance at Station **G** (Texas) is scheduled for 5:00 Central daylight time, during morning twilight, at position angle 302°.

A grazing occultation is predicted for more northerly observers, for example in Indiana and Illinois. Additional prediction data may be found in the Sky and Telescope Occultation Supplement (December, 1960, page 349).

MINOR PLANET PREDICTIONS

Dembowska, 349, 10.1. July 30, 22:12.9 −24-12. August 9, 22:05.3 −24-57; 19, 21:56.5 −25-34; 29, 21:47.7 −25-58. September 8, 21:39.7 −26-05; 18, 21:33.6 −25-54. Opposition on August 20th.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MOON PHASES AND DISTANCES

Last quarter	July 5, 3:33
New moon	July 12, 19:12
First quarter	July 20, 23:14
Full moon	July 27, 19:51
Last quarter	August 3, 11:48

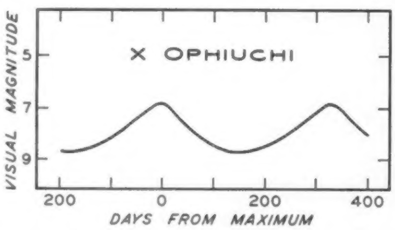
July	Distance	Diameter
Apogee 15, 11^h	252,400 mi.	29′ 25″
Perigee 28, 9^h	222,200 mi.	33′ 25″
August		
Apogee 11, 17^h	252,600 mi.	29′ 24″

MINIMA OF ALGOL

July 3, 11:55; 6, 8:44; 9, 5:32; 12, 2:21; 14, 23:10; 17, 19:59; 20, 16:48; 23, 13:36; 26, 10:25; 29, 7:14.

August 1, 4:02; 4, 0:51; 6, 21:40.

These minima predictions for Algol are based on a recent timing by D. Engelkemeir, and an assumed period of 2.8674 days. The times given are geocentric; they can be compared directly with observed times of least brightness.



This mean light curve for X Ophiuchi was derived from observations made by members of the American Association of Variable Star Observers.

X OPHIUCHI

NEAR the point where the summer constellations Ophiuchus, Aquila, and Hercules meet is the Mira-type variable star X Ophiuchi, at right ascension 18^h $36^m.0$, declination +8° 42′ (1950 coordinates). Maximum brightness of about magnitude 6.8 is forecast for around July 9th this year. At no stage in its 334-day cycle does this object fade out of reach of a 3-inch telescope, minimum light being about 8.6. Ever since its variability was detected by the English amateur T. E. Espin in 1886, X Ophiuchi has been a favorite with visual observers.

The light changes have certain marked peculiarities. Minima are comparatively shallow and flat, and differ very little from cycle to cycle, although, like other Mira stars, the maxima are quite varied in height. These facts suggest that X Ophiuchi is a close double star, whose variable component is sometimes much brighter, at other times fainter than its constant companion. Thus at minimum the latter star would be taken for the variable.

This is actually the case, for W. J. Hussey with the Lick Observatory 36-inch refractor found a 9th-magnitude companion only 0.3 second south of the variable. Later micrometer measurements have established very slow orbital motion in this visual binary. At Mount Wilson, P. W. Merrill ascertained that the variable is of spectral class *M*6e, the constant companion of class *K*0. Hence, X Ophiuchi, as seen unresolved in amateur telescopes, should appear red at maximum and yellow at minimum.

JUPITER WITHOUT SATELLITES

An unusual event takes place on September 27th, when Jupiter will appear without its bright satellites — all four being either in occultation, eclipse, or transit. This will occur when Jupiter is below the horizon for American observers, but the sequence of events will be visible from Japan and Australia. The following timetable is given by the *American Ephemeris*.

At 13:30 Universal time all four moons will be visible, **I** to the west of Jupiter, **II, III,** and **IV** to the east. At 13:56, **III** begins a transit across the face of the planet, and **II** transits at 15:16. The two remaining satellites will vanish nearly simultaneously, **I** going behind the west limb of the planet at 15:59, **IV** entering eclipse in Jupiter's shadow at 16:00.

Jupiter will seem to have no moons until 17:30, when **III** passes off the disk, ending its transit, **II** doing the same at 18:05. Next, **I** emerges from eclipse at 19:29, and **IV** similarly reappears at 20:40.

Jupiter last appeared moonless on September 20, 1949, and will do so again on June 27, 1966. Remarkably, on April 9, 1980, the phenomenon will occur *twice* in one night, satellite **III** emerging from occultation and promptly vanishing again into eclipse while the others remain invisible. For a list of occasions in the 19th and 20th centuries when Jupiter is without visible satellites, see the *Journal* of the British Astronomical Association for November, 1931, page 12.

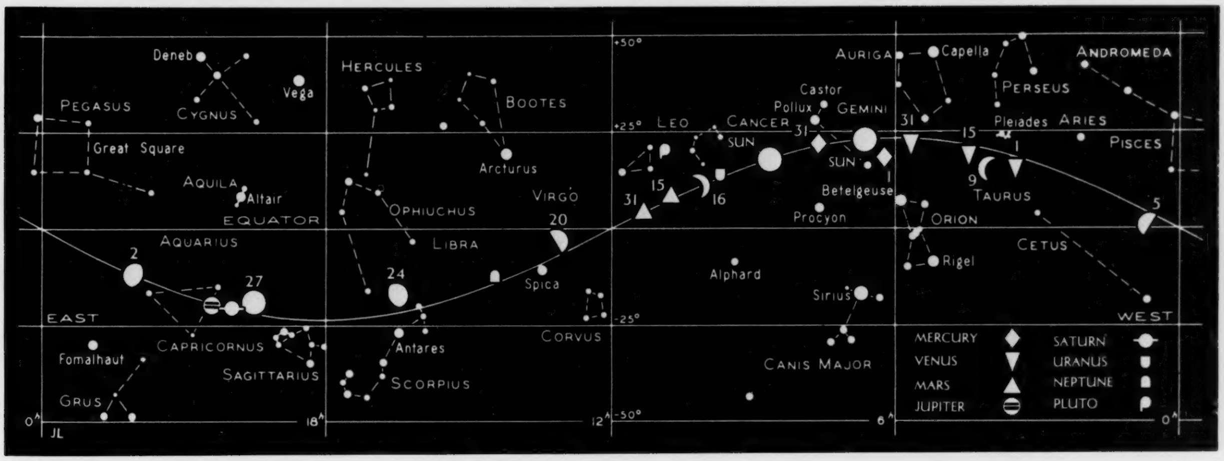
JULY METEORS

The moon, which is full on July 27th, will interfere with observations of the Delta Aquarid meteors, at maximum two days later. Under more favorable conditions, a single observer might see about 20 meteors per hour at the peak of the 20-day shower. On the 29th the radiant will be just west of Delta Aquarii, at right ascension 22^h 36^m, declination −17°; this point will move east and slightly north almost a degree per day.

WILLIAM H. GLENN

UNIVERSAL TIME (UT)

TIMES given in Celestial Calendar are Universal time (Greenwich civil time) unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th and to 10:15 p.m. PST on the 14th.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury is stationary in right ascension at 19^h Universal time on July 8th, before beginning eastward (direct) motion among the stars. On the 19th it reaches greatest western elongation, 20° from the sun, rising about 1½ hours before it. Mercury will be about as bright as Capella, then some 30° northwest of the planet. For a week before and after elongation, Mercury will be far enough away from the sun to be seen. Its disk will be near quarter phase, which will be reached on the 23rd.

Venus is the most brilliant object in the morning sky, of magnitude −3.7 on the 15th, about 100 times as bright as 1st-magnitude Aldebaran, which will be 3° south of the planet as the latter passes through the Hyades during the middle of July. Venus' disk appears in a telescope slightly gibbous, at midmonth 62 per cent illuminated and 18″.6 in diameter.

Mars is an inconspicuous object in Leo this month, of magnitude +1.8 and with a disk only 4″.4 in diameter on the 15th. It may be seen very low in the west as evening falls.

Jupiter reaches opposition to the sun on the 25th, 381 million miles from the earth. It rises in Capricornus just before sunset, and is visible the whole night as an object of magnitude −2.3 in the southern sky. Telescopically, its disk is 48″.1 in equatorial diameter and 44″.9 in polar.

Saturn, in Sagittarius about 6° west of Jupiter, reaches opposition on July 19th, 837 million miles from Earth, when its magnitude will be +0.3. The planet's slightly flattened disk has an equatorial diameter of 18″.5 and a polar one of 16″.6. The moon will pass 3° north of Saturn at 7^h UT on July 27th.

Uranus is in Leo, poorly placed for observation this month, for it sets at the end of evening twilight.

Neptune is an 8th-magnitude object in westernmost Libra, with 1950 co-ordinates 14^h $26^m.4$, −12° 37′ on the 15th. It crosses the meridian before sundown and sets in the southwest before local midnight. The planet's tiny greenish disk is 2″.4 in diameter. On the 21st, Neptune becomes stationary in right ascension, as it resumes eastward motion in the heavens.

WILLIAM H. GLENN

VARIABLE STAR MAXIMA

July 4, RU Cygni, 213753, 8.0; 9, T Hydrae, 085**008**, 7.8; 9, X Ophiuchi, 183-308, 6.8; 12, V Cancri, 081617, 7.9; 24, T Aquarii, 204**405**, 7.7; 29, R Octantis, 055**686**, 7.9; 29, R Pegasi, 230110, 7.8.

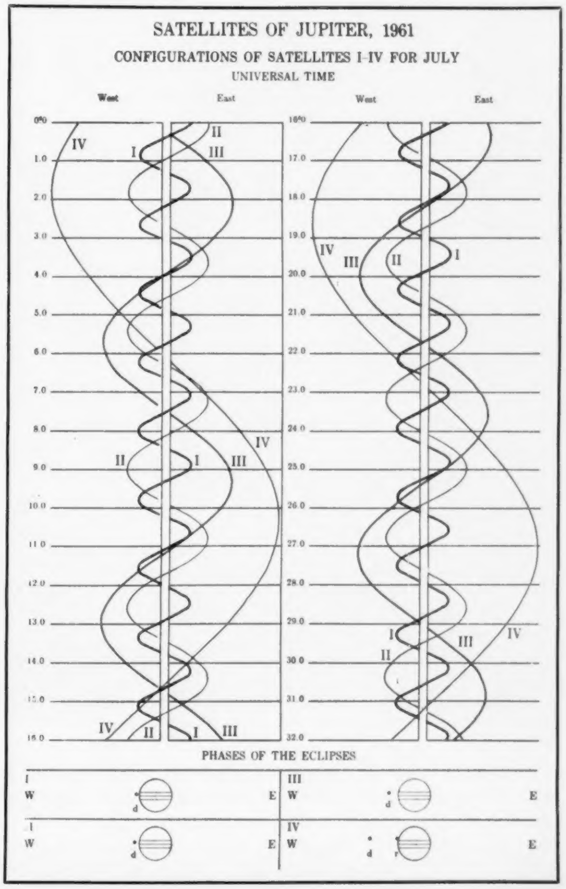
August 6, T Eridani, 035**124**, 8.0; 9, W Ceti, 235**715**, 7.6.

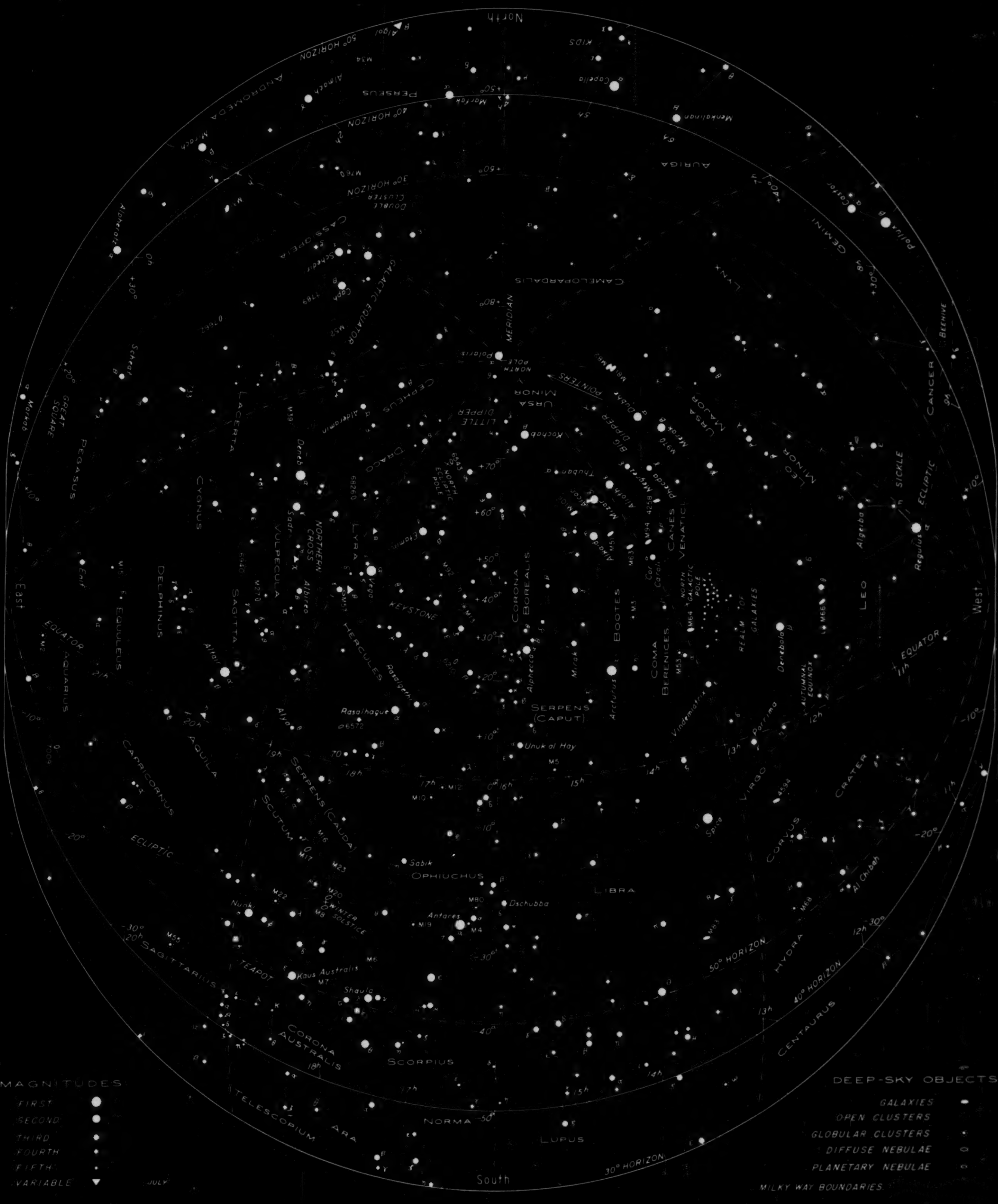
These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

JUPITER'S SATELLITES

The four curving lines represent Jupiter's four bright (Galilean) satellites: I, Io; II, Europa; III, Ganymede; IV, Callisto. The location of the planet's disk is indicated by the pairs of vertical lines. When a satellite passes in front of Jupiter, its curve crosses the lines. If a moon is invisible because it is occulted by Jupiter or is in its shadow, the curve is broken.

For successive dates, the horizontal lines mark 0^h Universal time, or 7 p.m. Eastern standard time (4 p.m. Pacific standard time) on the preceding day. Along the vertical scale, 1/16 inch is about seven hours. In this chart, west is to the left, as in an inverting telescope for a Northern Hemisphere observer. At the bottom, "d" is the point of disappearance of a satellite in Jupiter's shadow; "r" is the point of reappearance. From the "American Ephemeris and Nautical Almanac."





STARS FOR JULY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of July, respectively; also, at 7 p.m. on August 7th. For other dates, add or subtract ½ hour per week.

The forepart of Serpens, the great snake grasped by Ophiuchus, is just past the meridian at chart time. Its head is marked by an equiarmed "X" of five stars; from there the constellation may be traced through Alpha, a yellow 3rd-magnitude star in the snake's neck.

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S1853	12.5 mm. (½")	Ramsden	4.50
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S1355	32 mm. (1¼")	Plossl	12.50
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● **FREE RUBBER EYESHIELD** ● with S1405

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ADAPTER PLATE AND TUBE. Aluminum tapered tube and adapter plate, black anodized and finished in black crackle. Slides into our 5" O.D. Aluminum Tubing No. S1511. These parts are used with the eyepieces above to make a Rich-Field Telescope. Details in our catalogue.

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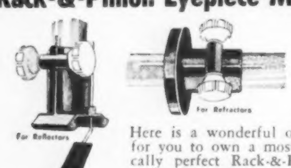
Cat. No. S1593 1¼"-diam. ADAPTER for eyepiece above .... **3.95 ppd.**

An Economical Eyepiece

This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. S1911 Coated .... **$5.90 ppd.**
Cat. No. S1991 Not Coated .... **5.25 ppd.**

Rack-&-Pinion Eyepiece Mounts



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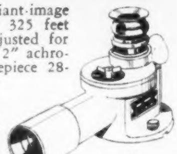
Cat. No. S1982 DIAGONAL HOLDER .... **1.00 ppd.**

8-Power Elbow Telescope



8 x 50

This telescope has a brilliant-image 48° apparent field; actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

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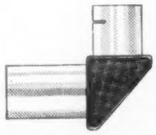
Star Diagonals



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Diagonal houses an excellent first-surface mirror, flat to within ¼ wave. Important accessory for refractor telescopes.

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Made of cast aluminum with black crackle finish. Each ring has three locking wing screws for adjusting. Base has two holes for mounting screws, and fits any diameter tubing. Easy to attach. Ring mount No. S1963 will accommodate finder above.

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New Prismatic Telescope

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Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¼". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs. All coated optics.

FIVE EYEPIECES

Power	Field at 1,000 yards	Exit pupil diam.	Relative Brightness
15x	122 ft.	5.4 mm.	29
20	81	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. S2052 .... **$59.50 ppd.**

60-mm.-diam. Scope. Same as above but with smaller objective. Equipped with same five eyepieces — 15x, 20x, 30x, 40x, 60x. Coated. With tripod.

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4" Reflector Telescope

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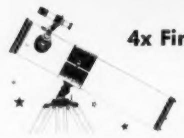
4x Finder — Wood Tripod



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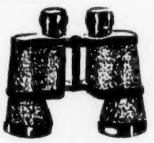
LOW, LOW PRICES!

American Type



"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design. Individual Focus (IF) or Center Focus (CF).

Cat. No.	Size	Field at 1,000 yards	Type	Price, ppd.
S1149	6 x 15 IF	360 ft.	Opera	$12.75
S1436	6 x 30 CF	395	"Zeiss"	18.75
S1435	6 x 30 IF	395	"Zeiss"	16.75
S1438	7 x 35 CF	341	"Zeiss"	20.75
S1437	7 x 35 IF	341	"Zeiss"	17.95
S1771	7 x 35 CF	341	American	23.50
S1439	7 x 35 CF	578	American*	35.00
S2191	7 x 50 CF	530	American**	42.50
S1106	7 x 50 CF	372	"Zeiss"	24.95
S–961	7 x 50 IF	372	"Zeiss"	22.50
S1503	7 x 50 CF	372	American	32.50
S1443	8 x 30 CF	393	"Zeiss"	21.00
S1229	8 x 30 IF	393	"Zeiss"	18.25
S1108	10 x 50 IF	275	"Zeiss"	26.75
S1442	20 x 50 CF	183	"Zeiss"	33.75

*Wide-angle 11° **Wide-angle

Add 10% Federal tax to all prices above.

Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. S1576 .... **6 x 30** .... **$10.00 ppd.**
Cat. No. S1577 .... **8 x 30** .... **11.25 ppd.**
Cat. No. S1578 .... **7 x 35** .... **12.50 ppd.**
Cat. No. S1303 .... **7 x 50** .... **14.75 ppd.**
Cat. No. S1579 .... **16 x 50** .... **17.50 ppd.**
Cat. No. S1580 .... **20 x 50** .... **20.00 ppd.**

New! Zoom Binoculars

Six different powers at your fingertips in the same binocular: 7x, 8x, 9x, 10x, 11x, and 12x. Positive fingertip control accomplished by rotation of eyecups. Popular Center Focus, American type, 40-mm. objectives, all coated optics. Complete with carrying case and straps. **Add 10% Federal tax.**

Cat. No. S2303 .... **$39.75 ppd.**

● **FREE CATALOG** ●

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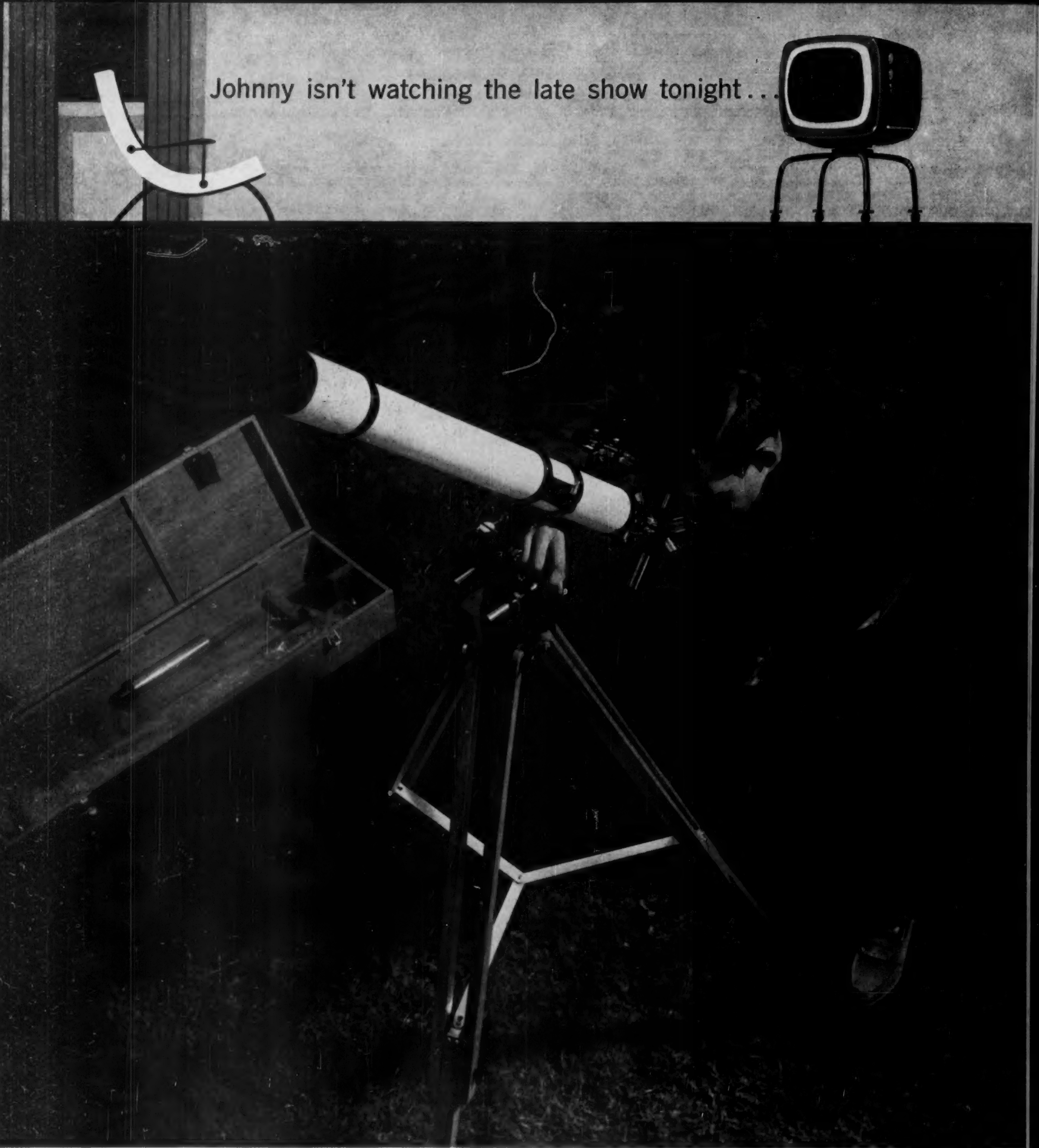

See pages 36 and 37.